Seven Matched Hollow Gold Jaguars from Peru's Early Horizon

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DEDICATION

THIS PAPER is dedicated to the late Dudley T. Easby, Jr., whose insistence on a full understanding of the technological realities of any artifact encouraged him and others to a broader and richer interpretation of material culture and of technology. His studies of Pre-Columbian metallurgy in the Andes, and particularly in Mesoamerica, were prototypes for the use of laboratory studies, ethnography, and ethnohistory in elucidating the technological side of man as it is manifest archaeologically in his material world. Easby had a genuine feeling for the smiths of whom he wrote and whose work he so thoroughly appreciated and, along with Paul Bergsøe and William Root, he established the foundation upon which current research in these areas proceeds today. His audience was large, and he saw to it, by publishing many of his articles in Spanish, that his colleagues in the Americas could enjoy and evaluate his interpretation of their own cultural heritage.

It is with gratitude and encouragement that we dedicate this paper to him.

ACKNOWLEDGMENTS

We would like to express our thanks to many individuals whose cooperation, advice, and hard work contributed substantively to this research.

To the curators of the various museum collections who granted us leave to study the jaguars: Allen Wardwell, most especially for his interest, encouragement, and permission to remove samples discreetly from the Chicago specimen; Wolfgang Haberland (Hamburg); Miguel Mujica Gallo (Lima); David G. Carter (Montreal); Pinkney Near (Virginia).

To the scientists and laboratories who extended their research facilities to us and carried out some of the analytic work: Pieter Meyers and Lambertus van Zelst (Chemistry Department, Brookhaven); Alan Parkes (Geology Department, M.I.T.); Florence Whitmore and Nancy Stouffer (Research Laboratory, Museum of Fine Arts, Boston).

To Henry Shawah for expertly reproducing the Peruvian sweat-welding technique; Cyril Stanley Smith for assisting in our metallographic interpretations and for critical evaluation of the manuscript; James Howard, Jr., for his photographic help; Philippa Shaplin for helping to organize the study in its early stages.

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Milwaukee jaguar (Access. No. 34008). Photo courtesy of the Milwaukee Public Museum.

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Introduction

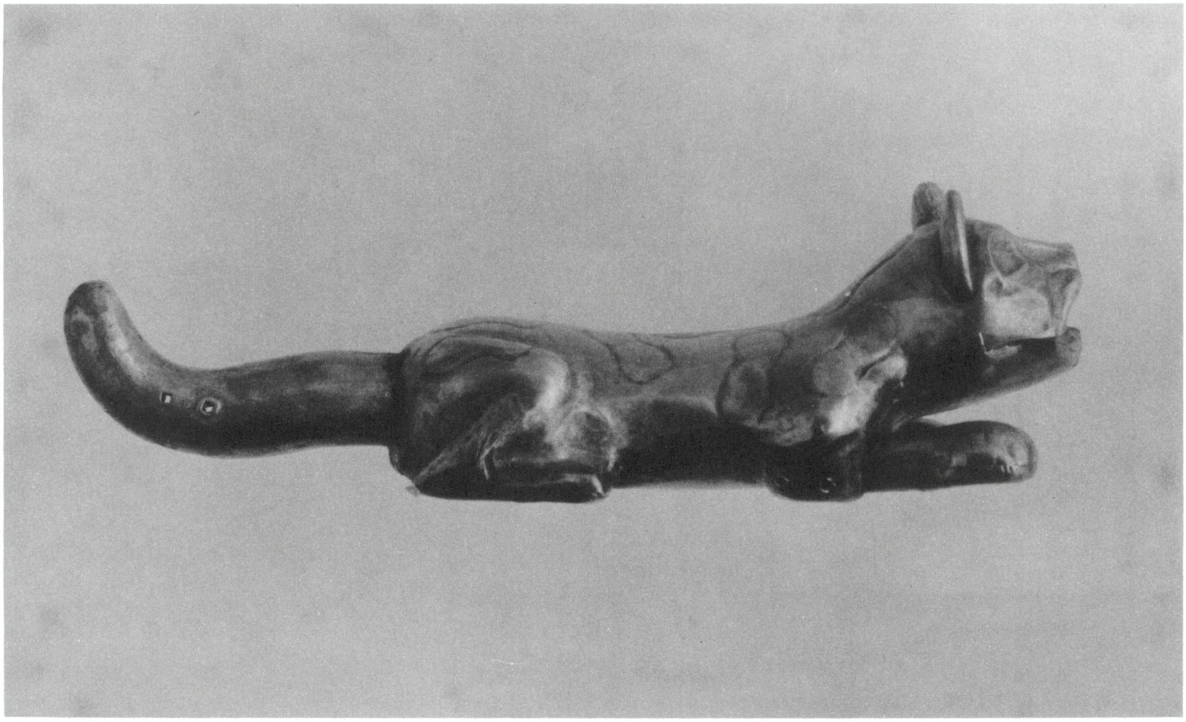
IN 1962, LEE PARSONS' attention was drawn to a small, hollow, gold jaguar in the Milwaukee Public Museum collections (Frontispiece and Fig. 1), when he learned that a similar animal had been acquired by the Montreal Museum of Fine Arts (Fig. 2). Montreal then informed him of a duplicate at the Virginia Museum of Fine Arts in Richmond (Fig. 3). He spotted a fourth at the Museum für Völkerkunde in Hamburg, Germany (Fig. 4), and a fifth at the Mujica Gallo Museo "Oro del Perú" in Lima (Fig. 9). Recently the Art Institute of Chicago acquired a sixth example (Figs. 5–8). It will not be surprising if one or two more gold jaguars of this series eventually come to our attention in Peruvian collections.[1]

The Milwaukee specimen had aroused Parsons' curiosity initially because catalogue and supplementary archival information proved its provenience to be Chongoyape in the Lambayeque Valley—the source of the best-documented Early Horizon Chavín gold, now for the most part in the Museum of the American Indian, Heye Foundation, in New York (Lothrop 1941). He then informed the late Samuel Lothrop of the history of the Milwaukee piece. Since it had been collected the same year, from the same landowner and the same *hacienda* as the Heye Museum's Chavín gold, Lothrop surmised that it also belonged to the Chavín (late Cupisnique) style and included the object in the 1961 Boston Museum of Fine Arts exhibition, "Twenty-Five Centuries of Peruvian Art" (Lothrop 1961: Cat. No. 4).

In assembling the 1968 exhibition, "The Gold of Ancient America," Allen Wardwell was able to bring together in Boston three of the gold jaguars—those from Milwaukee, Montreal, and Virginia (Wardwell 1968: 20, 21). We were fortunate in having the opportunity to examine all three in the Research Laboratory of the Museum of Fine Arts, comparing them detail by detail.

Each jaguar is a composite of twelve shaped pieces of hammered sheet gold, joined at the seams to form the hollow figures. There is a pair of perforations on each side of the tail, and there are also pairs of holes on both sides of the lower body, immediately behind the forelegs. The jaguar in Lima has three extant gold disc-bangles that hang from thin straps of metal fitted into the holes in the tail. As this is the only instance of such attachments, we wonder if they are not mod-

[1] Indeed, a seventh example came to light early in 1975 after the manuscript was submitted for publication. We can at least include a photograph of this late-comer for visual comparison with its mates (Fig. 10). Jaguar "Number Seven" is presently on display at the Staatliches Museum für Völkerkunde in Munich. It is on loan to that museum from a private collector, and we are grateful to both Dr. Otto Zerries of the Munich museum and the owner of the object for permission to publish the photograph. We also thank Dr. Wolfgang Haberland of Hamburg for bringing this gold jaguar to our attention.



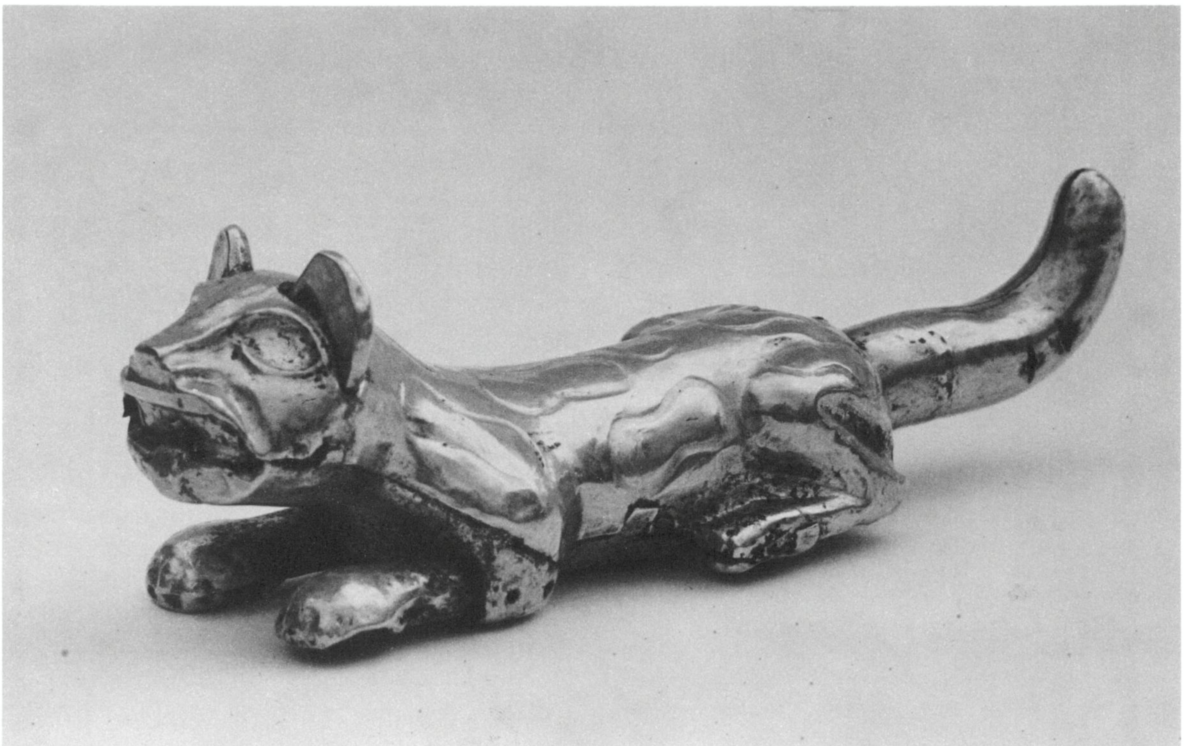
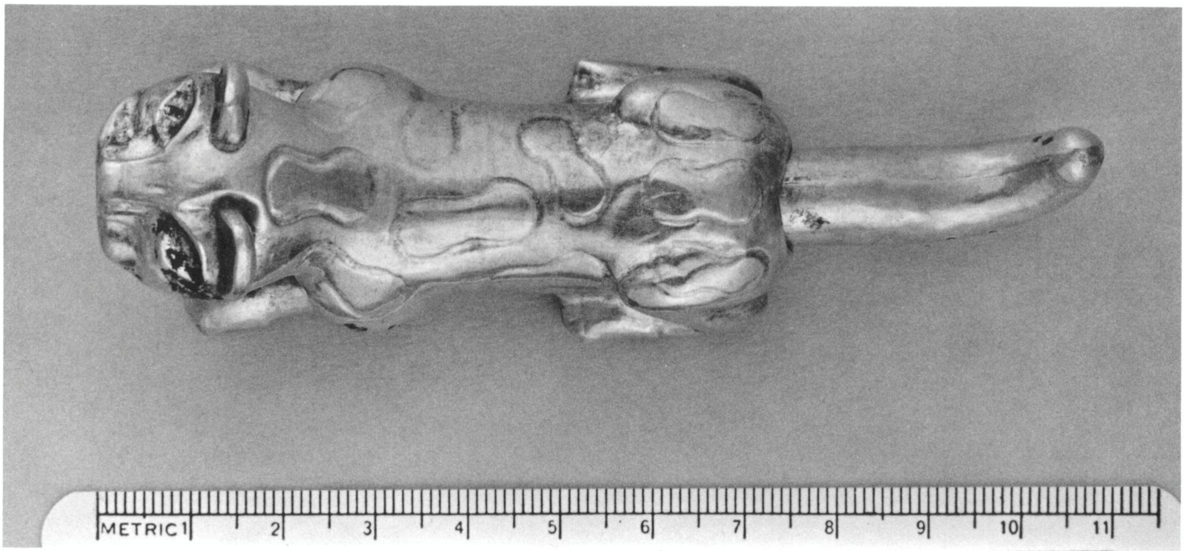


Fig. 1 (left, above) Milwaukee jaguar. Photo courtesy of the Milwaukee Public Museum.

Fig. 2 (left, below) Montreal jaguar (Access. No. 60.Ad.1). Photo courtesy of the Montreal Museum of Fine Arts.

Fig. 3 (above) Virginia jaguar (Access. No. 59–28–9). Photo Courtesy of the Virginia Museum of Fine Arts, Richmond.

Fig. 4 (right) Hamburg jaguar (Access. No. 27.118.1). Photo courtesy of the Museum für Völkerkunde, Hamburg.



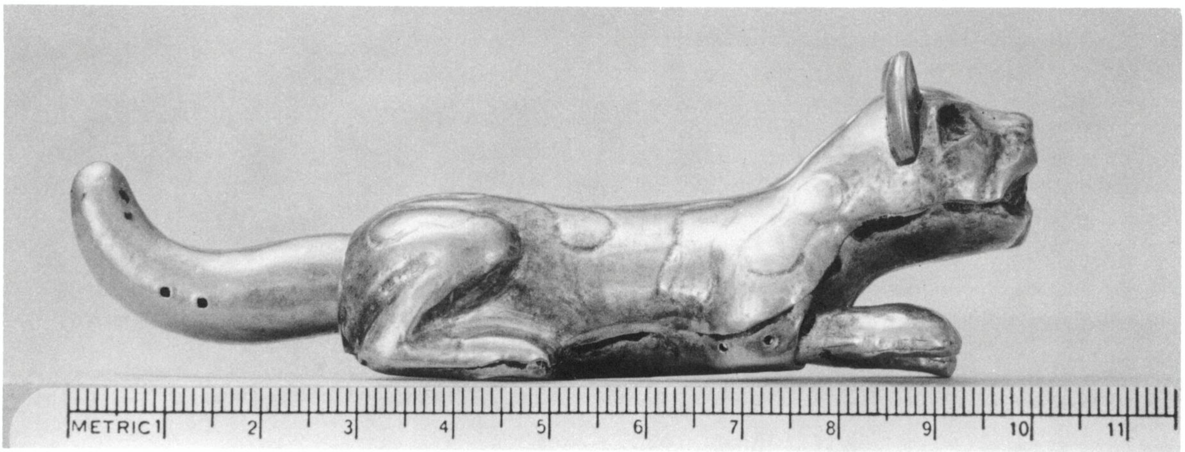


Fig. 5 (top) Chicago jaguar (Access. No. 70.420). Top view. Courtesy of the Art Institute of Chicago.

Fig. 6 (above) Chicago jaguar. Side view.

Fig. 7 (left) Chicago jaguar. Front view.

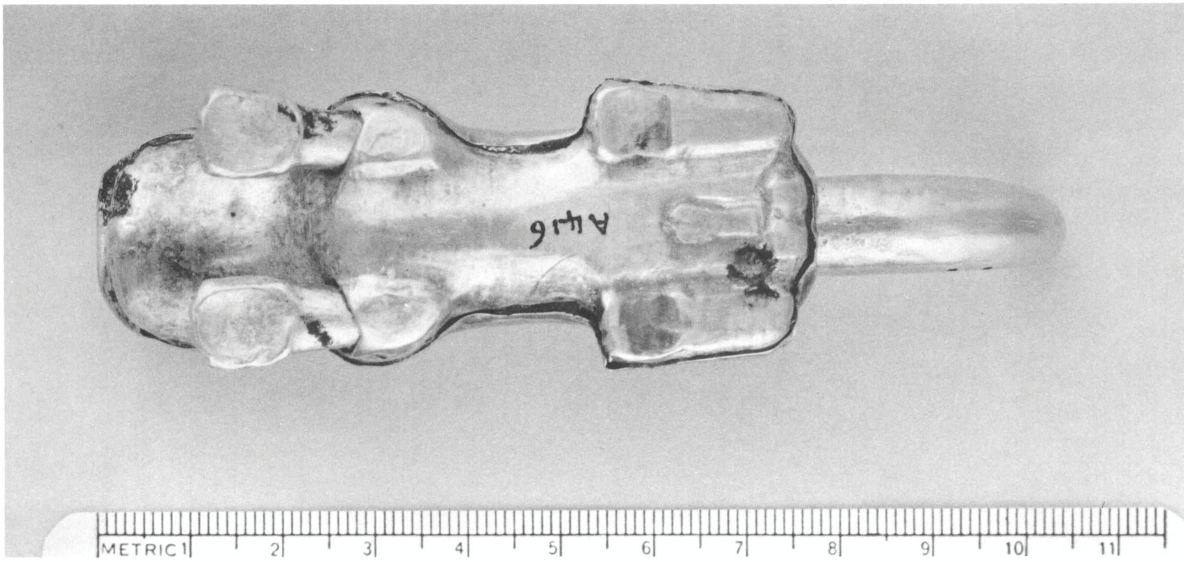
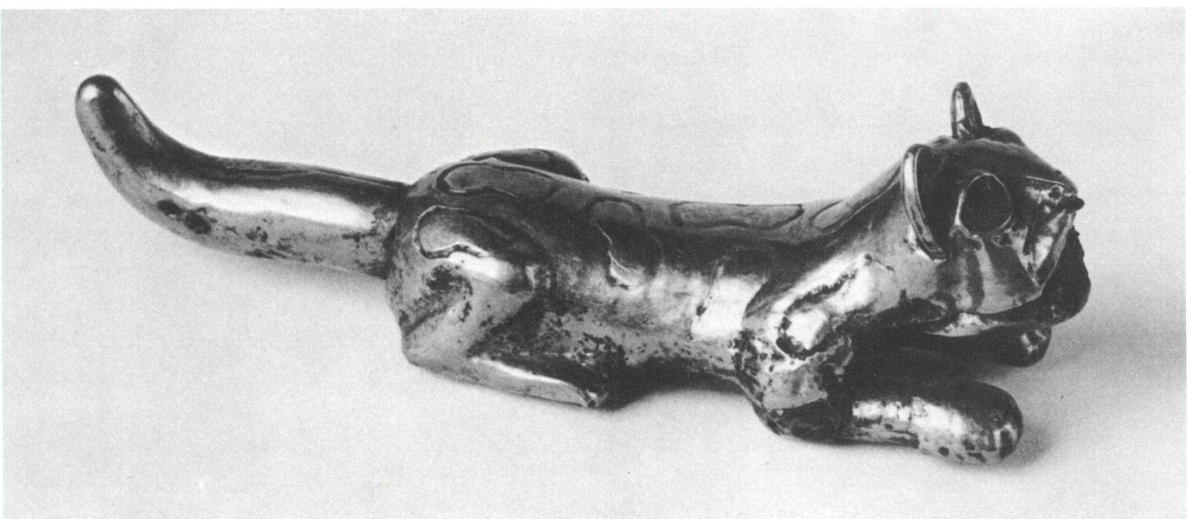


Fig. 8 (above) Chicago jaguar. Bottom view.

Fig. 9 (left) Lima jaguar (Access. No. 2514), as depicted on a 5.60-*sol* Peruvian postage stamp. Museo "Oro del Perú," Lima.

Fig. 10 (below) Munich jaguar (private loan). Photo courtesy of the Museum für Völkerkunde, Munich.



ern additions, as the inlaid turquoise eyes on the Virginia jaguar certainly are.

The presence of pairs of perforations suggests that these ornaments were originally sewn to a headband, shirt, or belt. If the danglers from the tail on the Lima example represent the original condition of the whole set, the jaguars might have been strung together through the front holes, with the heads facing upward, to create a composite necklace. They were apparently meant to rattle when used, for both the Montreal and Virginia animals contain a pebble. The Montreal jaguar rattles when shaken, but the pebble in the Virginia example, originally loose, has become lodged inside a hind leg and was only discovered when it appeared on the X-radiograph made of that animal. In any event, all seven might well have been made as a group for the same personage and buried in the same grave. Our technical examination demonstrates that they were fabricated in the same workshop by one goldsmith or by a group of supervised craftsmen.

History and Provenience of the Jaguars

CONSIDERING the wide dispersion of the gold jaguars in recent decades, museum documentation is unusually good. Records show that three of the seven were first collected in the Lambayeque Valley in 1927 or 1928. The Milwaukee and Hamburg catalogues are the most reliable in this regard. The Milwaukee jaguar was collected in 1928 by the family that owned Hacienda Almendral outside of Chongoyape. While the famous Chavín graves yielding gold were found about that time and at the same place, there obviously is no assurance that the jaguars were associated with the specific graves reported by Lothrop (1941), although the contents of those graves were widely scattered by the small boys who discovered them. The jaguar in Hamburg was collected in 1927 by Enrique Brüning from a goldsmith at Chiclayo, the city at the mouth of the Lambayeque River valley. Chongoyape is fifty kilometers inland. The specimen in the Miguel Mujica Gallo "Gold Museum" in Lima, like the Milwaukee example, originated with the owner of Hacienda Almendral near Chongoyape in the "late 1920's" (Mujica Gallo, personal communication). Unfortunately, we have been unsuccessful in securing a photograph of this example, though an illustration may be found in the privately published catalogue for the Gold Museum (Mujica Gallo 1968: Cat. No. 2514). It is also listed in a catalogue for an exhibition of that collection held in Brooklyn and San Francisco (Mujica Gallo 1963: Cat. No. 373). A color engraving of the Mujica Gallo jaguar was issued on a 5.60-*sol* Peruvian postage stamp which we illustrate in Figure 9. The specimen now in Chicago, although it has changed hands at least three times, had an original bill of sale from Peru dated 1928. The two in Montreal and Virginia have been traced to one old private collection on Peru's North Coast, but these also have changed hands several times. Most museums owning the objects favor a Mochica rather than a Chavín stylistic attribution.

In our estimation, the gold jaguar effigies under discussion are conceivably "Chavinoid" in descriptive terms, but are most probably proto-Mochica or Early Vicús culturally, and would therefore date approximately to 400–100 B.C. They are quite naturalistic and lack the interlocking upper and lower fangs of Chavín feline expressions. The jaguar motif itself was fundamental to most Pre-Columbian Peruvian cultures, and, as Michael Kan (1972) has pointed out, it is common to many of the art styles of the north Peruvian cultures in the Early Intermediate Period. The change from the impelling, fanged Chavín felines to the more generalized, naturalistic forms of the

Early Intermediate renditions, particularly on pottery, is already evident in the late Chavín transitions of Cupisnique and Tembladera.

Parsons finds the closest parallel to the gold jaguars technologically and stylistically in a small, hammered and soldered, hollow, gold frog effigy collected in the Vicús region farther north in the Piura Valley (Emmerich 1965: Fig. 15; Wardwell 1968: Cat. No. 9). This ornament also has pairs of suspension holes. There has been no technical examination of the frog, however. Its description here as a hammered and soldered piece is taken from the publications cited, but no verification of these details has been made. Whether it resembles the jaguars closely in terms of the particular technical characteristics we have determined for them as a group has not been investigated. Other objects of similar style, and constructed from pieces of sheet gold that have been joined metallurgically, are now assigned to the Vicús and Frias cultures of the far North Coast (Sawyer 1968: 28). Of this group, the hollow gold female effigy with detachable head in the Museo Arqueológico Brüning at Lambayeque (*ibid.*: Cat. No. 132) combines metallurgical and mechanical joins (the distinction between

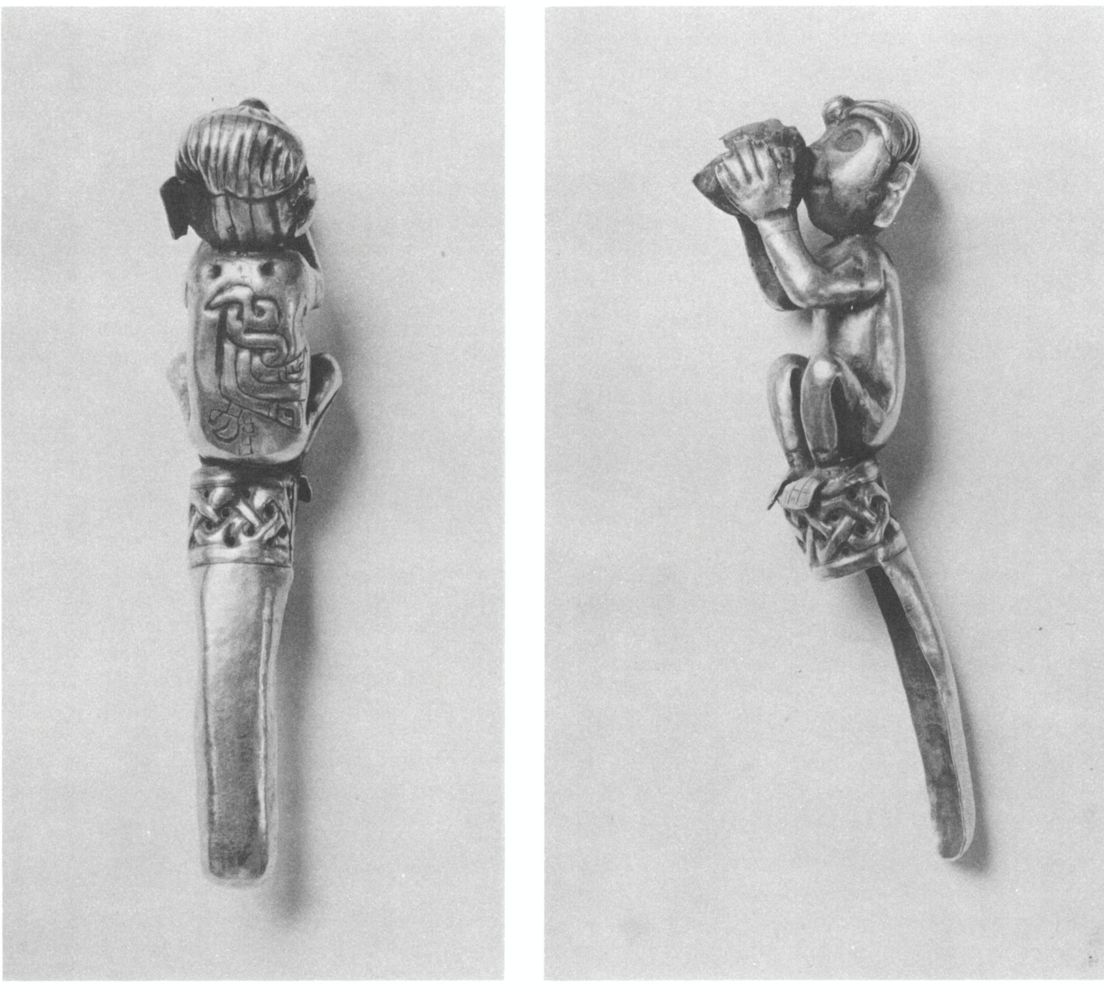


Fig. 11 Chavín spoon (Access. No. B–440.PG). Dumbarton Oaks Collections, Washington.

these two types of join is made below), while the so-called *comadreja*, or weasel, in the Mujica Gallo collection (1968: Cat. No. 3056) is assembled exclusively by metallurgical joins, as are the jaguars. Some of the joins on the *comadreja* exhibit a silver-colored solder, whereas others, such as those of the tail, appear to have been made with an alloy of the same gold color as that of the animal itself. The significance of the color of the metal at a join is discussed in the section on metallurgical joins.

Strikingly, the closest parallel to the jaguars from the point of view of technical style alone seems to be the Chavín-style spoon, atop which sits a man blowing into a silver conch shell, described by Lothrop (1951: Fig. 77*a*) and presently in the Robert Woods Bliss Collection, Dumbarton Oaks, Washington, D.C. (Fig. 11). This spoon and others associated with it have the characteristic suspension holes, and all contain pellets that rattle. Lechtman examined the spoon briefly at Dumbarton Oaks in 1971 and was struck by the similarity in joining procedures it seemed to manifest when compared with the group of jaguars. Her notes, made upon examination of the surfaces of the spoon, follow.

The metal appears to be of gold of high purity; object made of many pieces, soldered or welded together. Parts such as the legs are made of two pieces with a central seam, the seam almost invisible. These seams look entirely golden, and are extremely reminiscent of similar seams used for similar joins on the Peruvian gold jaguars. In contrast to these, there are other joins, usually at major anatomical body joints, where the soldering material is clearly a silver solder. The solder color is either metallic silver or dark gray to black, the color of the corrosion products of silver. Such solder is used in the following joins:

Head	→	Neck
Feet	→	Spoon base
Buttocks	→	Spoon base
Arm sockets	→	Torso (?) – possibly
Thighs	→	Torso (?) – possibly.

In addition, there are places, such as the ears, where the join to the head appears to have been made by crude welding, where the material used for the join did not become very molten, and is now granular and porous.

Should further careful examination of the spoon indicate that the techniques are as close as they appear to be, we would certainly wish to reconsider its cultural assignment to Chavín as well as the possibility that both this spoon and the animals may have come from the same or similar grave lots.[2]

[2] During the course of a recent field season in Peru, and subsequent to the writing of this paper, Heather Lechtman held an interview with Ing. Victor Baca A. in the North Coast city of Chiclayo on 29 June 1974. Ing. Baca related the precise circumstances of the discovery of the jaguars in 1925 on the Hacienda Pampa Grande, 17 km. southwest of Chongoyape, which, at that time, belonged to his father, Sr. Victor Baca. There is now no doubt about the precise provenience of the jaguars. They were found together inside the wrappings of a mummy bundle found on the eroded slopes of the Huaca "La Capilla" in Pampa Grande. This new information in no way alters the arguments put forward in the paper, but it does pinpoint the date, location, and circumstances of the original find.

A word-by-word transcription of Ing. Baca's account is given below, with his permission:

"En el verano de 1925, cayeron torrenciales lluvias en la costa norte del Perú; entre ellas, el Departamento de Lambayeque fue inundado por estas fuertes lluvias, y los ríos tomaron un formidable caudal de agua. El Río Chancay, en la estación de aforos de 'La Puntilla,' registró el 18 de Marzo de 1925 un caudal record de mil metros cubicos por segundo de agua.

"En su margen izquierda, frente a 'La Puntilla,' está ubicado un monumento antiguo (Incaico), denominado 'La Capilla,' que es un gran adoratorio construido integramente de adobones. Poco después de la caida de estas lluvias, un campesino que vivía en la Hacienda Pampa Grande estuvo por los alrededores de 'La Capilla,' buscando a un asno de su propiedad que se le había extraviado. En su búsqueda, observó que aquellas lluvias habían originado derrumbes de algunas plataformas de 'La Capilla,' y le llamó la atención que, de una de las paredes que se había caido, sobresalia un bulto; y lleno de curiosidad este campesino se acercó para verlo de cerca, y se dio cuenta que era un fardo funerario; y con su machete lo rompió para abrirlo, y encontró en su interior un cadaver que se encontraba envuelto con mantas, y en su interior encontró varios objetos de oro, entre ellos seis jaguares de laminas de oro.

"Este campesino todos estos objetos de oro los colocó dentro de su alforja y regresó a su casa muy sorprendido y nervioso. Al siguiente día viajó a la Provincia de Pacasmayo, y según lo que el manifestó vendió gran parte de este hallazgo a un comerciante extranjero ambulante. Poco después, regresó nuevamente a su casa construida dentro de un lote de terreno que tenía alquilado en Hacienda Pampa Grande.

"En aquella época, la Hacienda Pampa Grande la explotaba

The Vicús region was not exploited by *huaqueros* until 1962, after which great quantities of this style appeared on the market. On the basis of ceramic analysis, it has been suggested that

> The Classic Vicus ceramic style is closely related in many ways to that of the early periods of the Mochica culture found in the Chicama and Moche Valleys some 200 miles to the south. . . . The historical relationship between the two centers is as yet not understood and we know little about the early periods in the extensive valleys which lie between them. (Sawyer 1968: 25)

The Lambayeque Valley, the presumed source of the seven gold jaguars, is geographically midway between these two culture centers and is known primarily for the Early Horizon Chavín graves at Chongoyape and for the abundant ceramic collections in museums which are late stylistically (Wari and Chimú contemporary). It is one of the least explored regions archaeologically, however. The Vicús and Mochica contemporary period in this area is as yet undefined, and investigation there would go far towards explaining the intriguing variant Vicús culture centering in the Piura Valley. Our group of gold ornaments has been assigned provisionally to the beginning of this period. We must depend upon future field investigators to discover the ceramic and total cultural complex associated with it.

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los Señores Victor Baca y Don Enrique Baca. En un principio, no se supo nada del hallazgo efectuado por este campesino, pero después se difundió el rumor de que algo había sucedido, pues se le vio que ese campesino disponia de dinero. Cuando el Sr. Victor Baca se enteró de este rumor, hizo llamar al campesino, quien le confesó su hallazgo. Entonces Don Victor Baca, quien era su patron, le dijo: Has hecho muy mal en haberte hido fuera de la hacienda para efectuar la venta de las piezas de oro que encontraste, pues yo también te la hubiera comprado y pagado buen precio. Entonces, el campesino, como quería y apreciaba a su patron, el Sr. Baca, le dijo: Yo he guardado algunas piececitas, pues no vendí todo el lote. Y se fue a su casa y le trajó mostrandole dos jaguares de los seis que había encontrado, y el Sr. Victor Baca le entregó quinientos soles de esa época, como pago.

"Como Don Victor Baca era socio de su tío, Don Enrique Baca, le entregó un jaguar y el otro jaguar le conservó para si. Don Victor Baca lo tuvo en su poder muchisimos años, y frecuentemente lo mostraba a todas las personas que tenían interés en observarlo. Muchas de estas personas querían adquirirlo, pero Don Victor Baca no lo vendió. Posteriormente, después de muchisimos años, el Sr. Miguel Mujica Gallo, amigo del Sr. Baca, le rogó que le cediera en venta este jaguar para incorporarlo a la colección de oro que estaba organizando. Entonces el Sr. Baca accedió, dada esta finalidad. El otro ejemplar de jaguar, en poder de Don Enrique Baca, no sabemos su último destino."

Although Ing. Baca was aware of the discovery of only six jaguars, it is clear that a larger number was originally found within the wrappings of the mummy bundle, since we have now located a seventh (see footnote 1). This is not at all surprising, given the fact that the shepherd who uncovered them sold several before Ing. Baca's father learned of the find and acquired the two that remained with his family. Since the jaguars were dispersed almost immediately after they were discovered, we cannot be sure of their original number.

Goldsmithing Techniques

THE PERUVIAN metallurgical tradition is overwhelmingly a sheet-metal tradition. Metal objects in the round were generally conceived not as castings, but as forms produced by joining individual, preshaped pieces of metal sheet in the configuration desired. Peruvian metallurgy was, perforce, a metallurgy preoccupied with techniques of joining, whether mechanical or metallurgical in nature. The distinction between these two types of join has been made elsewhere:

> A mechanical join consists of interlocking parts. . . . A metallurgical join, on the other hand, consists of parts that are bonded together by interatomic forces so that they become a single, continuous piece. Such bonding is produced either by locally melting the surfaces to be joined or by introducing molten metal between them. (Lechtman and Steinberg 1970: 6–7)

Just as some of the most inventive aspects of Andean metallurgy, both in Colombia and in Peru, centered about solutions to the problem of creating golden surfaces on metal that was not gold in color, so too the Peruvian penchant for building metal forms by assembling their parts went hand in hand with a rapidly expanding repertoire of sophisticated methods for accomplishing metallurgical joins. That such techniques were developed quite early in the course of Peruvian smithing is clear from the presence of soldered and welded joins on many of the Chavín-style objects, described by Lothrop (1941, 1951), from Chongoyape and possibly from Chavín de Huántar itself. Although no detailed laboratory examination has been made of these pieces, Lothrop distinguished quite carefully between joins he observed as soldered and those made by welding. Both the late Dudley T. Easby, Jr., and Cyril Stanley Smith have reported the presence of solder, or of some metallurgical joining technique involving molten metal, on some of the Chongoyape pieces they were personally able to examine in the collection of the Museum of the American Indian, Heye Foundation, New York (personal communications).

Evidently, there are good reasons for investigating the metallurgy of Peruvian joining procedures in some detail. A sufficient number of such studies would certainly reveal, if it existed: (a) any progression or trend in the use of alloys for soldering, demonstrating the changing capacity of smiths to recognize as well as to control alloy systems and the temperatures at which they fuse; (b) any regional peculiarities setting apart the technical style of the smiths of one area or culture as different from those of others practicing at the same time; and (c) the products of individual "workshops," recognizable by virtue of the distinctiveness of the techniques used in their manufacture.

On the basis of laboratory analyses of Andean metal artifacts, we can now set out with some confidence the chronology of the major developments in the production and use of specific metals and alloys in Peru from the earliest cultural appearance of metal there (Grossman 1972) up to the Spanish invasion; we can also begin to trace the changes that occurred in the preferred techniques for gilding metals—from the early examples of simple, mechanical sheathing in gold to the much later series of complex depletion gilding methods (Lechtman 1973). It may well be that our data on metallurgical joins will similarly show the kind of development in those procedures that would allow correlations between join type and date and/or region of manufacture.

Taken all together, a full library of such technical information ought to suggest new ways of controlling and organizing the large body of unexcavated metal artifacts that continues to appear in Peru. It should also aid in our attempts to characterize the flexibilities and possibilities for change and development within a smithing tradition whose basic approach to the handling of metal changed remarkably little during its entire course.

The Products of One Workshop

THERE IS NO QUESTION that the jaguars were made in a single workshop, though we cannot be sure whether only one or several smiths had a hand in their fabrication. Table II compiles a series of careful measurements of various dimensions of these animals and of their weights. In Table I, we list analyses of the metal composition at their surfaces as obtained either by X-ray fluorescence measurements or by neutron-activation studies.

The jaguars are all made of a similar sheet metal whose composition is 8.9% copper, 14.9% silver, and 75.9% gold (see Table IV). The surfaces of the sheet are enriched in gold, however, for the average surface composition of the metal, as given in Table I, is 3% copper, 12% silver, and 84% gold. This surface enrichment probably occurred at two stages in the manufacture of the jaguars: (1) during the fabrication of the sheet itself when the copper oxide scale that formed on the surfaces of the metal upon annealing was removed; and (2) during the final cleaning procedures when any copper oxide scale formed on the surfaces as a result of heating during welding and soldering operations was removed. In both cases, the diffusion of copper out of the metal and the subsequent removal of copper oxide from its surfaces by some chemical treatment such as a mild acid or urine pickle would have left the metal surfaces enriched in silver and gold. Since the analyses show that these surfaces are slightly depleted in silver, it is likely that the final finishing operations involved a stronger pickle, such as copiapite and nitre [$Fe_2(SO_4)_3 \cdot nH_2O + KNO_3$] (Lechtman 1973), which could have been used briefly to clean the metal. By removing small amounts of surface silver as well as the copper oxide scale, the corrosive pickle effectively deepened the golden color of the alloy.

The metal sheet used for all of the jaguars is remarkably uniform in thickness. This was observable

TABLE I. COMPOSITION OF THE JAGUAR METAL—SURFACE ANALYSES

Percent, by weight

	X-ray fluorescence[1]						*Neutron activation*[2]			
	Site	*Cu*	*Ag*	*Au*	*Pb*		*Site*	*Cu*	*Ag*	*Au*
MILWAUKEE	lower body, rear	2.5	12.5	85.0	N.D.					
MONTREAL	lower body, rear	2.6	10.3	87.0	0.1					
VIRGINIA	lower body, rear	2.0	12.5	85.5	N.D.					
CHICAGO	lower body, rear	3.0	12.0	84.0	0.1	CHICAGO	lower body, rear	4.5	13.1	82.5
							lower body, front	4.1	13.3	82.8
							tail	2.4	10.4	87.3

[1] These analyses were performed at the Research Laboratory, Museum of Fine Arts, Boston.

[2] The metal samples were removed by stroking the surfaces lightly with small quartz cylinders or plates. The streaks of metal adhering to the quartz were then activated and analysed at the Brookhaven National Laboratory by Pieter Meyers and Lambertus van Zelst of the Chemistry Department. It was assumed that only Cu, Ag, and Au were present, and all compositions are therefore adjusted to 100%.

TABLE II. COMPARATIVE MEASUREMENTS OF THE GOLD JAGUARS[1]

	Total length[2]	*Upper body length*	*Lower body length*	*External tail length*	*Maximum tail width*	*Maximum body width (shoulders)*	*Maximum head width*	*Width at midriff*	*Height at midriff*	*Maximum body height (excluding ears)*	*Total tail length (from X-radiographs)*	*Total length, object's left front leg (from X-radiographs)*	*Weight (gm.)*
MONTREAL	10.95	7.15	7.25	3.40	1.10	2.95	2.45	2.05	1.85	3.00	3.75	2.20	22.0
VIRGINIA	10.65	7.15	7.40	3.45	1.10	3.10	2.35	2.10	1.75	3.00	3.95	1.95	21.1
CHICAGO	10.80	7.30	7.40	3.50	1.10	2.85	2.50	2.05	1.85	2.80	3.80	1.90	19.3
HAMBURG	10.85	—	—	—	1.10	3.05	2.35	2.05	1.85	—	—	—	—
LIMA	10.50	7.25	6.80[3]	3.35	1.10	3.10	2.45	2.05	1.80	2.95	—	—	21.6
MILWAUKEE	10.90	7.30	7.45	3.60	1.10	3.10	2.40	2.15	1.60[4]	2.75	3.95	2.05	21.0

[1] Recorded by calipers in centimeters to the nearest 0.5 mm., except where indicated.

[2] The least meaningful measurement, as total length depends upon the distance the tail was inserted into the body before soldering. The tails on the Chicago and Lima animals have come free and are now held in place with wax (Chicago) or a Duco-like cement (Lima).

[3] The measurements of the Lima jaguar were made by H.L., while those of the others (except Hamburg, which were supplied by Haberland) were made by L.P. Apparently the two investigators took this particular measurement at slightly different positions on the animals.

[4] This specimen is dented on the base; measurement not meaningful.

in the X-radiographs taken of the Milwaukee, Montreal, Virginia, and Chicago specimens and is also evident in the closeness in weight of all the animals. Since the ten dimensions measured on each animal (see Table II) prove them to be virtually identical in size, the small variation in their weights is a good indication of the uniform thickness of the gold sheet itself.

As was mentioned earlier, each animal is composed of twelve individual pieces. The body has an upper and a lower portion, joined along their common edges. Each extremity—tail, ears, front legs—is made of halves, joined along their midline. When he first examined the jaguars, Parsons suspected that these individual pieces might have been hammered over a common prototype, and this certainly seems to be the case for the upper and lower body pieces. Of the seven dimensions measured on each jaguar body, nowhere do these values differ by more than $\pm$ 2 mm., and in most cases the variation is smaller. Examination of the jaguars has not afforded any clues about the material of which the model was made—stone, wood, ceramic, or any other—but there is good evidence that the metal sheet was pressed down over the model and hammered or pushed into shape. Since the tail of the Chicago animal was removable, we were able to examine the inside surfaces of the body cavity. These proved to be extremely smooth, with no evidence of any hammering or other form of pressure exerted from the inside, as one normally sees in a piece made by the repoussé technique or one that has been pressed into a mould. On the outside, individual hammer blows are difficult to see, but there are areas where the metal stretched and buckled during shaping and was subsequently hammered down to flatten the buckling. The jaguar pelage markings in intaglio on the back of the animals (Fig. 5), and the genitals and rear paws in intaglio on their undersides (Fig. 8), were formed with a blunt, smooth, and probably soft tool that pressed the metal down into declivities already present on the model. The marks left by this smooth, burnishing type of tool are evident in many of these depressions. As the sheet was hammered and pushed into place on the model, it stretched somewhat, causing an unwanted increase in the total length of the free edges, i.e., the edges that now constitute the body seam. This excess metal was accommodated either by overlapping (often evident near the mouth as in Fig. 7) or by making a cut in the edge and folding over the extra metal. The latter procedure was used on the Chicago specimen below the hole made to accept the tail (Fig. 12).

It is harder to say whether or not the tail, ears, and front legs were also formed over a model. Their size and shape are so similar that one is led to believe there was a master model in full round. The very fact that each extremity is made in halves, which were later joined along their midline, suggests that they were not raised but were hammered over a form. Had they been raised, each extremity could have been made as a single piece.

The jaguars were assembled by joining the extremities to the body after the top and bottom body parts themselves had been joined (see below). Holes were made in the body to accept the extremities either by cutting out or punching out pieces of the body metal in the shape desired. In either case, the body cavity was probably filled with a material such as sand that acted as a soft backing against which the metal could be displaced. The remaining rough edges were pushed in to form a kind of flange around the opening. This produced a smooth, rounded contour at each opening (particularly clear at the socket for the front leg in Fig. 3), and also provided a larger surface area for the solder join between the body and the extremity (see the section on soldered joins below). The extremity—whether tail, front legs, or ears—was then pushed into its receptacle and soldered in place. The X-radiograph of the Chicago jaguar, shown in Figure 13, is representative of those taken of four of these animals and illustrates the general technique. The open ends of the front legs extend several millimeters inside the body cavity, as does the tail.

There are, of course, variations in the jaguars that are noticeable upon comparison. For example, the

characteristic jaguar pelage markings on their backs differ subtly in the depth of the depressions and in their spacing, but no more than would be expected from differences in pressure applied to the chasing tool or in the angle at which the tool was used. While all the tails are made of right and left halves, and all the ears of front and back halves (see Fig. 14), the front legs were not joined as consistently. Four of the animals have legs made of upper and lower halves (see Figs. 6, 7, and 15, for example); in the Virginia jaguar, both legs are composed of right and left halves (Fig. 3); and the Montreal specimen has one of each kind (Fig. 2). The greatest variation occurs in the number of tabs used to facilitate the joining of the upper and lower body parts (see below the section on joining techniques). The Chicago jaguar has no tabs, and the photographs of the Hamburg specimen also indicate none on that animal; the Milwaukee and Virginia specimens each have two; the Lima animal has four; and the Montreal jaguar has seven. The locations of these tabs along the body seam also vary from animal to animal (see Figs. 1, 2, and 3). Finally, there are differences in the size and shape of the perforations in the tails (Figs. 1, 2, 3, and 6).

These variations were almost certainly introduced either by a group of goldsmiths working on the objects at different times or at different stages in their manufacture, or by the normal idiosyncracies of a single craftsman who has to produce the same object many times in succession and does it slightly differently each time. In general, the similarities among the jaguars far outweigh their differences, and the characteristics they share virtually preclude the possibility that any one was made independently of the others.

One question that still remains unanswered is whether or not the surfaces of these gold jaguars were originally painted, either completely or in certain specific areas. All of them exhibit patches of an accretionary material, somewhat waxy in consistency and deep red-brown to black in color (e.g., Figs. 2, 3, 7, and 8). It does not have the usual appearance of a paint film, and it is distributed unevenly and rather sparsely on all the animals, yet its presence on them all should be explained. Lothrop (1951) describes several painted objects in the group of Chavín-style gold artifacts he studied, but in all cases the remaining traces of paint were easily identifiable as such. His remarks are worth quoting here.

> The subject of paint on metals has never been studied. It seems probable that many more specimens were painted than we now realize and that museums and collectors have destroyed the paint under the impression that they were removing the products of corrosion. I know of a gold plaque from which a red film, supposedly cuprous oxide, was scoured. When the plaque later was analyzed, it proved to contain no copper and little silver. It therefore must have been painted.
>
> It appears that all the pieces under discussion had been painted red or in one case black, either in whole or in part. . . . In the Chimu period, many centuries after Chavín, the use of paint on gold or silver again became common, especially in the Lambayeque region . . . , where green, black or red were employed. (*ibid.*: 227, 229)

We were able to remove only one tiny sample of this accretion-like material from the bottom of the Chicago jaguar at a site near the proper—that is, the animal's own—right rear leg (visible in Fig. 8). When it was removed, the gold underneath appeared quite red in color, perhaps from some prior chemical reaction between the impurities in the gold and the material that lay above it. The sample was analyzed by X-ray diffraction techniques. It is certainly not cinnabar, nor is it any of the sulphides or oxides of copper, silver, or iron. No positive identification was possible with the minute amount of material at our disposal. The question of the presence or absence of paint on these jaguars will have to remain an open one until more extensive sampling can be accomplished on all the specimens.

Joining Techniques Employed on the Jaguars

To REITERATE, each jaguar is assembled from twelve individual pieces of shaped sheet metal. All extremities—namely, the tail, ears, and front legs—are made of halves. Each tail consists of a right and a left half, butt-joined along their common edges; each ear consists of a front and a back half, similarly joined; and each front leg is made of either a bottom and a top half or a right and a left half, joined by the same method as the tail and the ears. The body is also made of two pieces, a top and a bottom, though these are quite different in size and shape and are not strictly speaking halves (Figs. 3 and 6 show this difference particularly well). The halves of each tail, ear, and leg were joined by a sweat-welding technique described in detail in a later section. The body, on the other hand, was assembled by soldering the top and bottom parts together. Afterwards each complete tail, ear, and leg was inserted into an opening prepared for it in the body and secured there with this same solder.

All the joins on these jaguars are thus either sweat-welded or soldered joins. Although some mechanical devices were used to help hold the units rigid while they were being joined, the joins themselves are entirely metallurgical. In fact, the technical sophistication of the jaguars lies in the way in which the two procedures, sweat-welding and soldering, were combined to produce strong and, equally important, inconspicuous joins.

THE SWEAT-WELDED JOINS

The *Metals Handbook* (1961, 1: 40) defines welding as

> Joining two or more pieces of material by applying heat, pressure or both, with or without filler material, to produce a localized union through fusion or recrystallization across the interface. The thickness of the filler material is much greater than the capillary dimensions encountered in brazing.

A fusion weld may, therefore, be achieved in a number of ways. (1) The two edges to be joined are brought into contact and heated locally until they begin to melt, at which point the two metals fuse. Upon cooling, the fused zone solidifies as one integral piece of metal, producing the join. (2) A filler material, of the same composition as that of the pieces to be joined, is introduced *as a solid* between the two edges. The filler is heated locally until both it and the edges it is joining melt and fuse, forming a continuous piece of solid metal upon cooling. (3) A filler material, of the same composition as that of the pieces to be joined, is introduced *in the molten state* between them. In this case, the heat from the molten filler raises the temperature of the edges being joined until those edges melt and fuse with the filler. Solidification at the joint proceeds in much the same way as in case (2). Lechtman and Steinberg (1970) and Steinberg (1973) give a good description of fusion welds used by the Romans to join portions of bronze castings by running molten metal of the same composition as the castings between the edges of the parts to be joined.

The joins on the jaguars are not true fusion welds, but come closest to weld type (2) just described. Although a material of the same composition as that of the parts to be joined is introduced as a solid between those parts, this material does not act as a filler because it is never allowed to melt completely, as it would in a fusion weld. Nevertheless, it is added for thermal reasons. Its temperature (and that of the edges adjoining it) is raised until only its surfaces melt or "sweat," the rest of the solid remaining unaltered. In this case, the bonding that creates the join results from the fusion of the *sweated surfaces* of the parts being joined with the *sweated surfaces* of the solid metal introduced between those parts. The flow of metal at the join is thus entirely a surface phenomenon, yet the surface fusion is sufficient to produce an effective join of solid metal upon cooling. For this reason, we have chosen to call such joins sweat-weld or sweated joins. The mechanisms of their formation will become clearer in the discussion that follows.

Unfused portions of this added metal, located

along the seams, are still quite visible on the exterior surfaces of the extremities. In fact, its appearance at seams is the most characteristic feature of the particular sweat-welding technique used on the jaguars, a feature which occurs on all the examples we were able to study in the laboratory. Some typical seams at the midline joins of the extremities are shown in Figures 14, 16, and 17. The differences are both striking and characteristic. Figure 17 illustrates the seam along the proper left leg of the Milwaukee jaguar. The added metal appears as a single, thin, rectangular strip running the length of the join, situated between the edges of the two original halves of the leg and raised slightly proud of the present leg surface. Figure 16 illustrates the underside of the proper left front paw of the Virginia jaguar. Here, there are two distinct strips of metal running the length of the seam. Where they are both visible they are raised proud of the paw surface. In some areas only one strip is visible, the other having disappeared, and in general they run an uneven course, sometimes touching one another, at other times slightly separating. The situation is still different at the seam joining the halves of the proper right ear of the Chicago jaguar (Fig. 14). Here the two strips occur side by side for a short distance near the base of the ear. One strip disappears, while the other travels along the seam, continuing over the curved ear top.

Fortunately for this investigation, the proper left front leg of the Milwaukee jaguar and the tail of the Chicago jaguar have come loose from the jaguar bodies, and can be removed or reinserted at will. This enabled us to examine the interiors of both those extremities. Figure 18 is a view into the hollow interior of the Milwaukee leg at the open end of the leg that ordinarily fits inside the body. The photograph shows the same seam whose exterior surface is depicted in Figure 17. Whereas the external seam appears as a single, rectangular strip of metal running along the join, the internal seam is clearly composed of two metal strips, one beside the other. Each of these is actually a hollow cylinder or tube of extremely thin metal. Both tubes remain in close association and run the entire length of the join on the interior of the leg. Figures 19 and 20 reveal a similar situation inside the tail of the Chicago jaguar. Both photographs show the structure of the inside seam near the open end of the tail. Again, the seam displays two hollow metal tubes that lie touching one another and run down along the join from one side of the opening (Fig. 19) to the tip of the tail and back up the opposite side to emerge again at the open end (Fig. 20). The tube at the left in Figure 20 has been squashed somewhat, making it rather flat in appearance.

With the tail in its normal position on the jaguar, approximately the last five millimeters of the open end are normally inside the body cavity and are therefore not visible (see X-radiograph in Fig. 13). We were granted permission by the Chicago Art Institute to remove a cross section through the seam, including the inner tubes, at the end of the tail that fits inside the jaguar body. The site from which this metal sample was removed is shown in Figures 21 and 22. Figure 21 (interior surface) shows the width of the sample (a total of 3.4 mm.), which included metal from each half of the tail well beyond the region of the join itself (this may be compared with Fig. 20 which shows the area before sampling). In Figure 22 (exterior surface), the tubular configuration of the added metal at the seam appears in cross section.

Examination of the sample removed from the tail revealed the main features of the joining procedure by establishing: (a) the composition of the metal introduced at the seam and the composition of the tail metal itself, i.e., the nature of the seam metal as a sweat-weld metal distinct from a solder; (b) the function of the cylindrical tubes of metal along the interior seams; and (c) the reasons for the differences in appearance among the various seams on the exterior surfaces of the extremities (Figs. 14, 16, and 17) and between the interior and exterior seams on any one extremity (Figs. 17 and 18).

a. Metal composition

Two tiny bits of metal were removed from portions of the tubes that appeared never to have been in con-

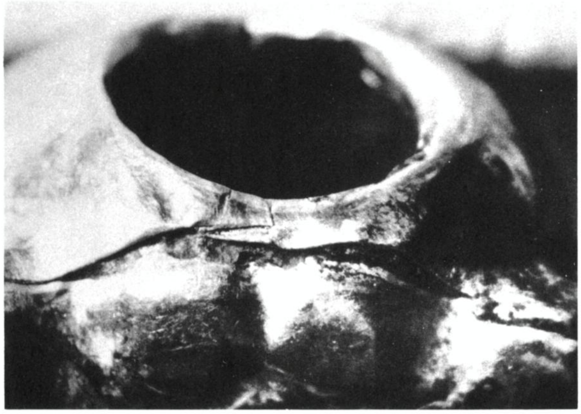
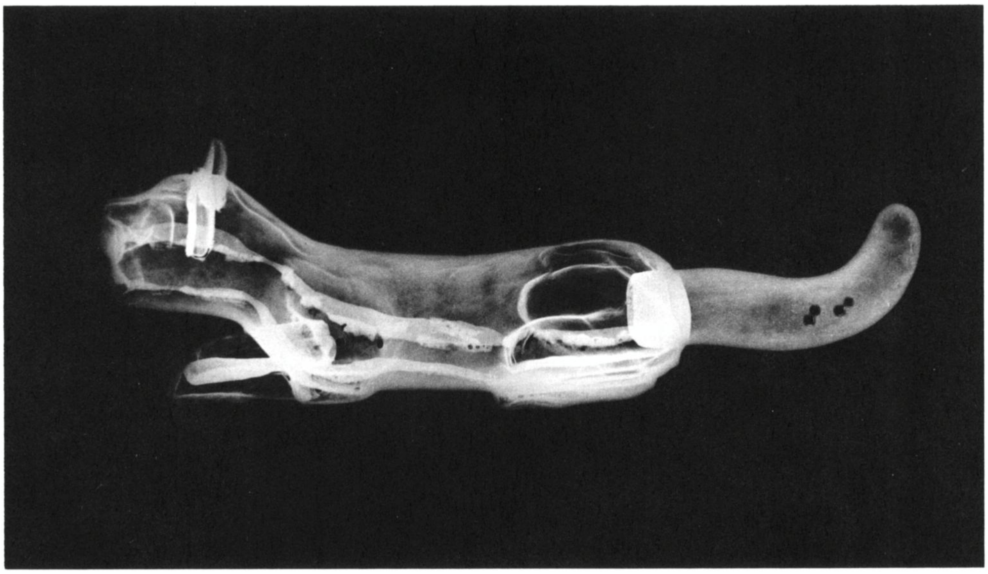


Fig. 12 (left) Chicago jaguar (x3.5). Detail of body seam beneath hole for tail. Note overlapping of metal at edge.

Fig. 13 (center) Chicago jaguar (actual size). X-radiograph. Note pallions of silver solder all along body seam.

Fig. 14 (below, left) Chicago jaguar (x7.5). Detail of seam at midline join of right ear, exterior surface.

Fig. 15 (below, right) Chicago jaguar (x5). Detail of seam at midline join of right paw, exterior surface.



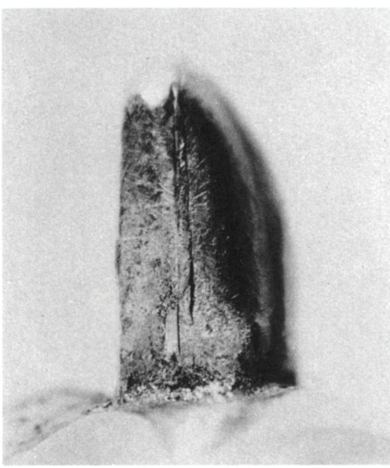
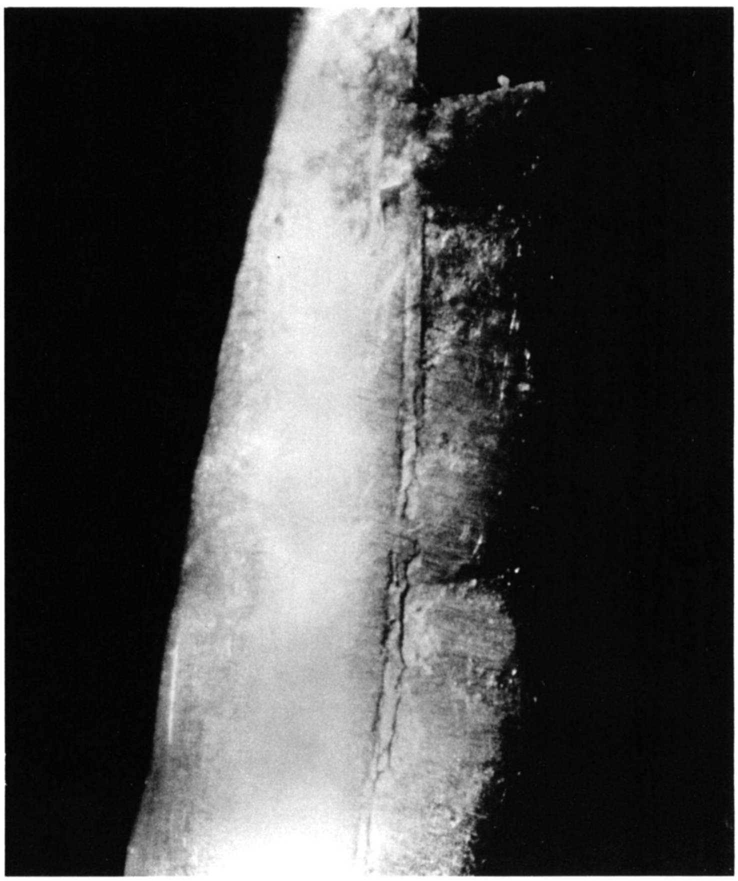
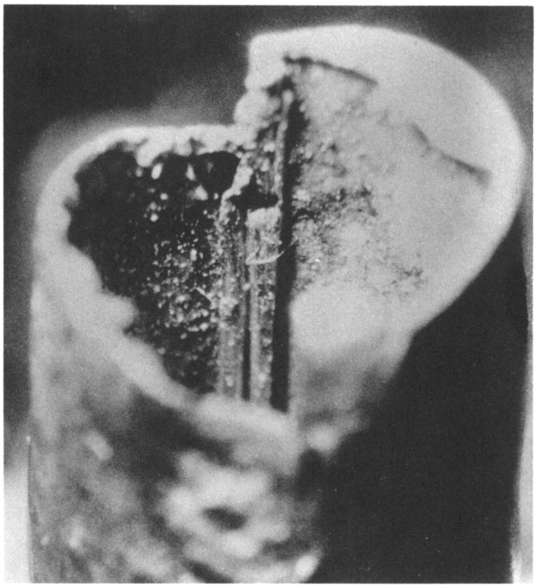
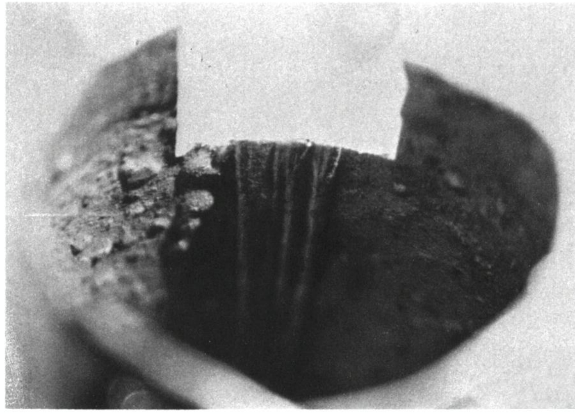


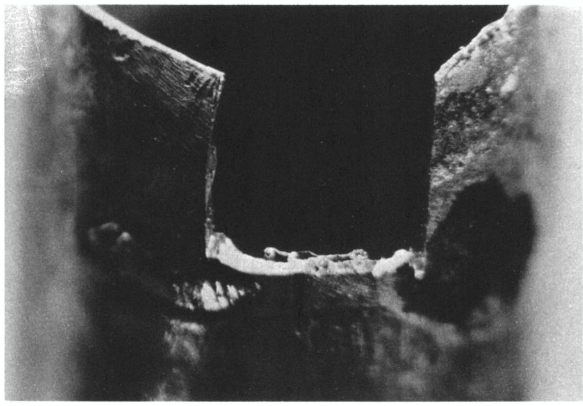
Fig. 16 (above) Virginia jaguar (x5.3). Detail of seam at midline join on underside of left front paw, exterior surface.

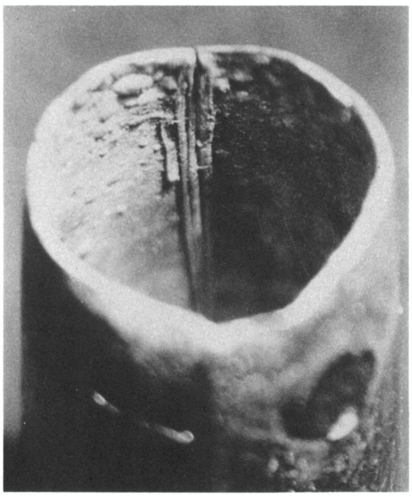
Fig. 17 (right) Milwaukee jaguar (x5.3). Detail of seam at midline join of left front leg, exterior surface.











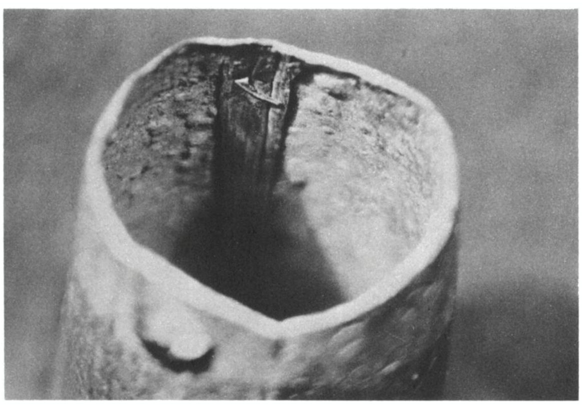


Fig. 18 (above, left) Milwaukee jaguar (x5.3). Detail of seam at midline join of left front leg, interior surface. Note the two adjacent metal tubes running down along the seam.

Fig. 19 (center, left) Chicago jaguar (x5). Detail of seam at midline join of tail, interior surface. Note metal tubes running along seam.

Fig. 20 (below, left) Chicago jaguar (x5). The opposite side of the seam from that shown in Figure 19.

Fig. 21 (top, right) Chicago jaguar (x7.5). Detail of open end of tail showing site from which sample was removed. Note tubes at seam and blisters on the interior surface.

Fig. 22 (above, right) Chicago jaguar (x7.5). Detail of exterior of tail at site from which sample was removed. Note characteristic tube-like configuration of added metal at seam, visible in the sawn section.

tact with the tail metal and are thus uncontaminated by it. One such fragment was taken from a tube on the sample removed from the tail (Fig. 20); the other was taken from a tube on the opposite side of the tail (Fig. 19). Both fragments were analysed by neutron activation for their gold, silver, and copper content; it was assumed that no other elements were significantly present. The results of these analyses are summarized in Table III.

TABLE III. COMPOSITION OF TUBE METAL FROM TAIL OF CHICAGO JAGUAR—NEUTRON ACTIVATION ANALYSIS[1]

	Percent, by weight		
	Cu	*Ag*	*Au*
Tube on metal sample removed from tail (Fig. 20)	9.0	15.6	75.4
Tube at opposite side of tail (Fig. 19)	7.9	20.0	72.1

[1] The neutron activation analyses reported in this paper were undertaken through the courtesy of Pieter Meyers and Lambertus van Zelst of the Chemistry Department, Brookhaven National Laboratory. The method measures the composition of the bulk sample, but effects due to absorption of radiation from the interior of the sample by the enriched gold surfaces were not determined.

Further analyses were performed on the metal sample removed from the tail to compare the composition of each half of the tail with the composition of the tubes at the join. The section was mounted, polished, and examined in an electron microanalyser with a beam size of approximately 2–3 microns. Quantitative analyses were made on the section at the locations shown in the photomicrograph illustrated in Figure 23. Table IV summarizes the microanalyser results. The analyses demonstrate unequivocally that the tail metal and the tube metal are the same alloy. The differences in composition between the tail and the tubes are no greater than the composition variations within the tail itself. The microprobe analyses also compare extremely well with the neutron activation results presented in Table III. The average composition of the tail metal determined by electron microanalyses (9.3% Cu, 14.7% Ag, 75.6% Au) is almost identical with the composition of one of the tube samples removed from the tail and studied by activation techniques (9.0% Cu, 15.6% Ag, 75.4% Au). Even at the precise locations where joining actually occurred, such as at points 5, 5a, 8, 8a, and 9 in Figure 23, we were unable to detect any significant differences in composition between the tail metal and the metal added at the seam. This is an interesting result, for it rules out the possibility that a copper oxide scale was deliberately produced at the seam to facilitate the formation there of the low melting point eutectic of copper and gold which would have occurred when the join was heated under reducing conditions. This alloy would have acted as a solder at the seam. It could also have been formed by introducing copper salts at the area to be joined; these salts are similarly reduced upon heating and form alloys with the gold. Such joining procedures were common among the early Greeks and Etruscans, and are characteristic of their finest gold granulation work (Hoffmann and Davidson 1965; Smith 1967). They were not used, however, by the Peruvian smiths who made the jaguars.

Finally, several probe traces were made across the section with the beam traversing a path through one tube, across the fused zone where the tube joins the tail metal, and on into the tail metal itself. The general direction of this traverse is shown in Figure 23. Two typical traces are illustrated in Figure 24. Trace A, which runs through only about one-half the section, indicates the changes in the composition of gold, silver, and copper along the beam path. No significant change is recorded for any of these elements. The trace reveals that the compositions of the tube, the tail metal, and the fused zone between them are identical within the limits of sensitivity of the instrument. The long, gentle slope of the curves in Trace A at the surface of the tube arises primarily from a rounding of the edge of the section at this location. Trace B, which records only gold and copper, indi-

TABLE IV. COMPOSITION OF TAIL AND ADDED METAL AT TAIL SEAM, CHICAGO JAGUAR

Electron microanalyser determinations made at locations designated in Fig. 23[1]

Point No.	Description	Percent, by weight Cu	Ag	Au
1	L tail-half	11.3	13.6	75.2
2	L tail-half	8.6	15.0	75.5
3	L tail-half	8.6	15.0	75.0
4	L tail-half	9.2	15.5	75.4
5	Join: L internal tube → tail	9.3	14.0	76.1
5a	L internal tube	9.9	14.2	76.3
5b	L internal tube	8.2	15.6	76.1
6[2]	L internal tube	6.4	12.9	74.8
7[2]	L internal tube	7.4	11.3	76.5
8	L internal tube	7.0	16.3	77.4
8a	Join: L internal tube → tail	8.5	15.5	77.0
9	Join: L external tube → tail	8.6	15.0	75.8
10	L external tube	8.1	14.1	76.5
11	R external tube, remnant	8.6	15.1	75.2
12	R tail-half	8.1	16.3	76.0
13	Join: R internal tube → tail	8.9	13.7	75.1
14[2]	R internal tube	7.7	12.4	74.6
15	R internal tube	8.4	14.9	75.8
16	R tail-half	9.8	14.5	75.0
17	R tail-half	8.7	14.7	75.3
18	L tail-half	9.9	14.1	76.3
19	R tail-half	9.5	13.7	76.4
20	R internal tube	8.4	15.9	75.5
	AVERAGE[2]	8.9	14.9	75.9

[1] The MAC electron microanalyser in the Department of Geology, M.I.T., was used for these analyses. All data were taken at 20 kv.; counting time was 30 seconds. The empirical method of Ziebold and Ogilvie (1964) was employed for determining the concentrations. Both the calibration of the ternary Cu-Ag-Au standards and the writing of a computer program for data reduction were undertaken by Alan Parkes, Geology Department, M.I.T.

[2] The relative error in the determination for Cu is ± 1%, for Ag ± 0.9%, and for Au ± 0.6%. The analyses made at points 6, 7, and 14 were not included in computing the average. The thinness of the sample at these points, together with the rounding of its edges, caused difficulty in maintaining a stationary beam spot. All three analyses are low by about 5%, the error coming mainly in the silver concentration.

cates a dip where the beam partially entered the mounting material at the junction of the tube and the tail (see Fig. 23). This declivity locates the position of the junction. Trace B was made across the entire section, from surface to surface. Both traces agree well with one another and corroborate the quantitative probe analyses given in Table IV.

All these data, obtained by a variety of techniques, leave no doubt that the metal tubes introduced between the two halves of the tail are made of the same alloy, the same sheet metal, as the tail itself. Their function as a sweat-weld material is discussed in the following section.

b. Design and function of the tubes

The mounted section removed from the tail was ground down a number of times so that the seam could be examined at various positions along its length. This enabled a general reconstruction to be made of the shape and position of the tubes relative to the two tail-halves before the halves were joined. Figure 25a illustrates the configuration of the seam metal prior to heating. Originally both edges of each tail-half were fitted with a kind of strip-clip that ran like a thin ribbon along the entire length of the edge. The clip was made of extremely thin sheet metal (0.02 mm.) whose ends were rolled into a tubular shape so that the ribbon would clamp onto the tail edge when pressed into place. Thus the tubular portions of each clip occurred at both the interior and exterior surfaces of the tail edge onto which it fitted. When the two halves of the tail were brought together and their edges butted, pressure was applied to force the clips into contact with each other. Undoubtedly some mechanical device was used both to maintain this pressure and to keep the two halves immovable during heating (as, for example, a strip of metal wrapped around the tail to bind the halves together). Figure 25b illustrates how a cross section through the seam would appear at this stage of the procedure. A large proportion of the surface area of the right clip is in contact with a similarly large area of the clip on the left. At the same time, the external

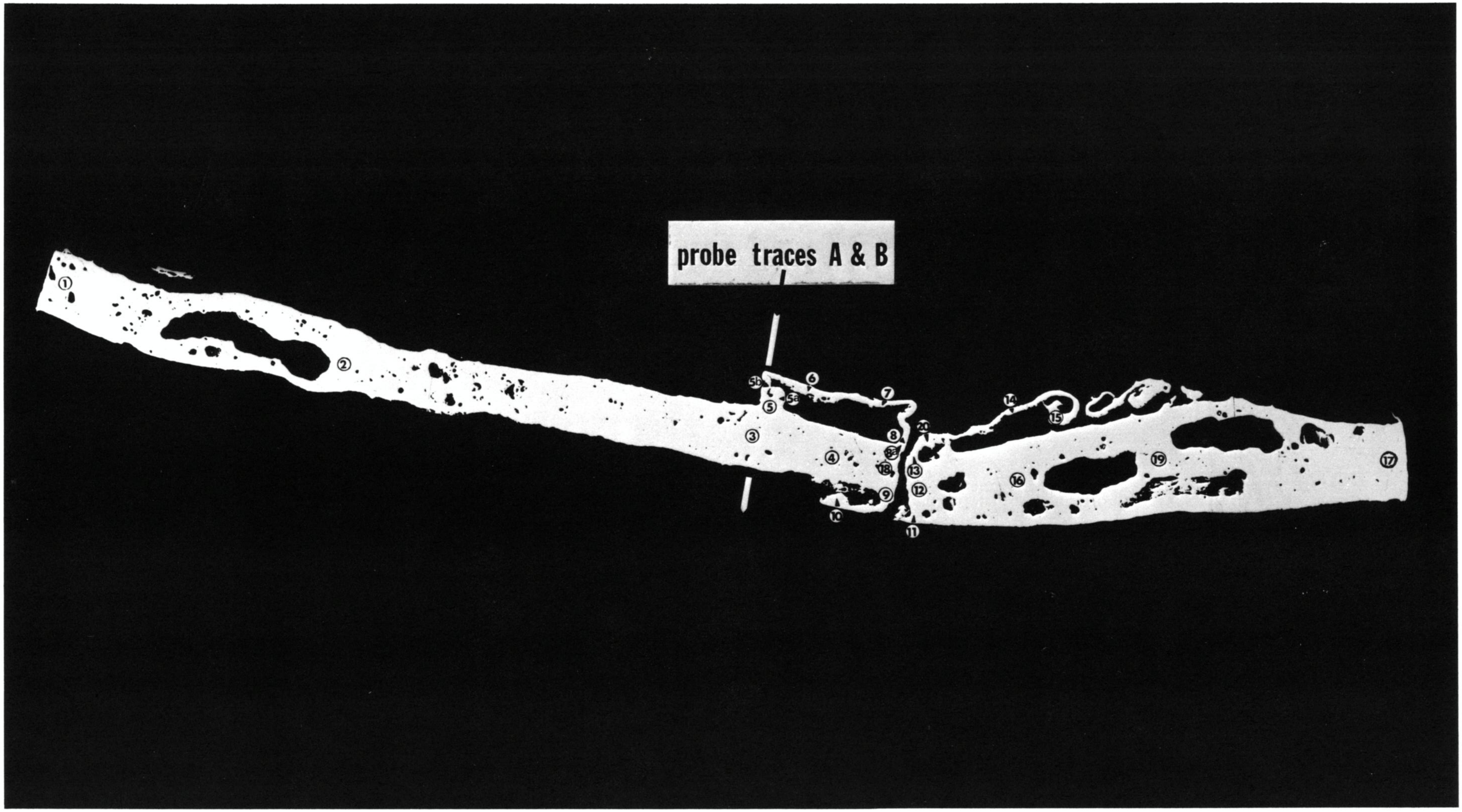
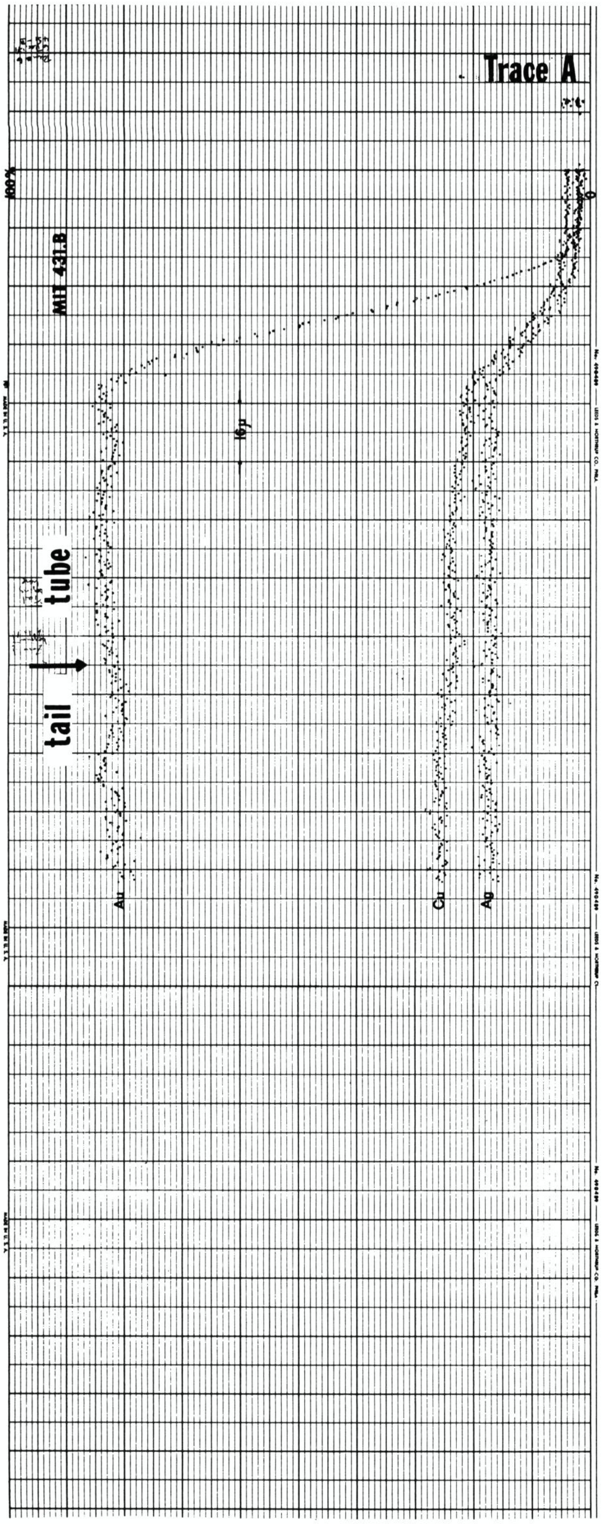
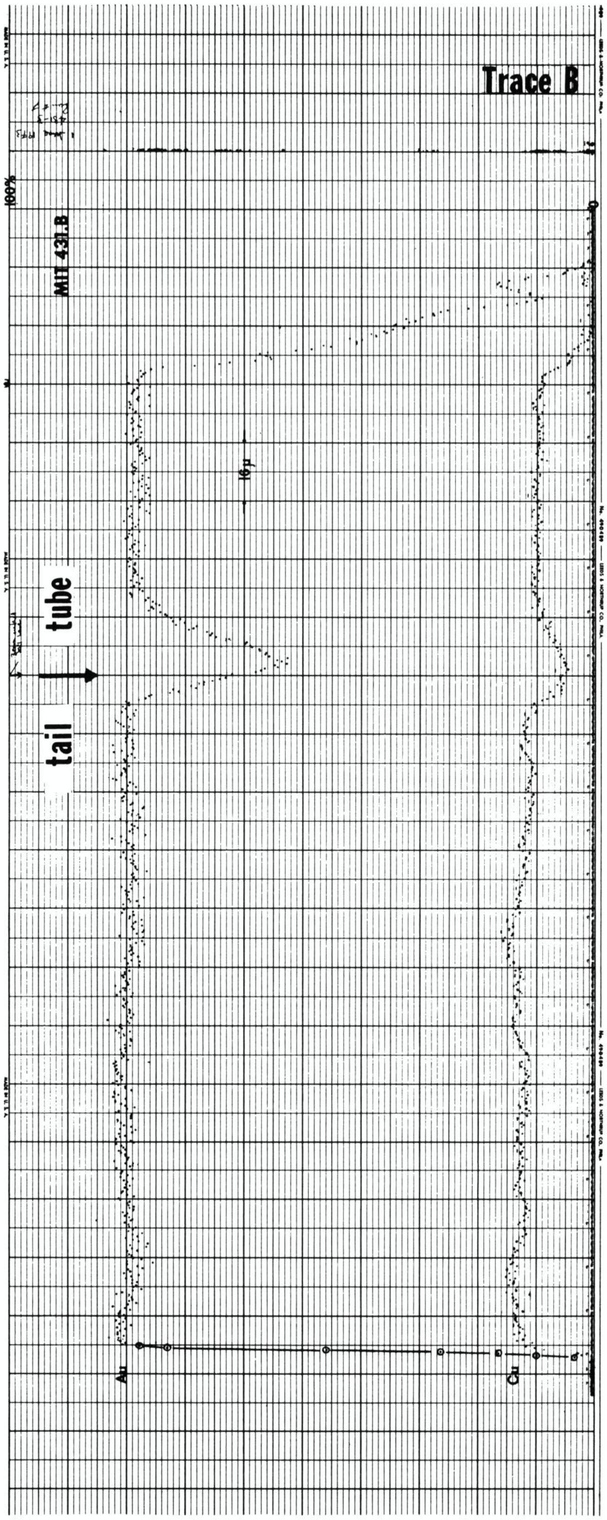


Fig. 23 (above) Chicago jaguar (x70). Photomicrograph showing cross section of sample removed from tail. Numbered points indicate locations where electron microanalyser data were taken and locate the metal compositions given in Table IV. Arrow shows direction of microanalyser trace.

Fig. 24 (below) Chicago jaguar. Electron microanalyser scans across the tail section shown in Figure 23.


Trace A
100%
MIT 431.B
16μ
tube
tail
Au
Cu
Ag


Trace B
100%
MIT 431.B
16μ
tube
tail
Au
Cu

pressure applied to the tail forces each clip up against the tail edge it is mounted on. In this way, good contact is made at all the surfaces that eventually must fuse to effect the join.

Introducing metal into this configuration at the seam provides a distinct advantage in that it greatly increases the surface area over which the join can be made by creating many points of contact where fusion and bonding can occur. Figure 25c illustrates in cross section three such possible types of join achieved by this design. In each case, the left and right halves of the tail are connected through the ribbon-clips, but the zone of fusion is different for each. At no one position is all the metal fused, yet the join remains viable because, all along the tail, one continuous bond is made at each position. The beauty of this design also lies in the ease with which the clips can be applied to the metal edges. The ribbon-clips are made of sheet metal hammered so thin (and then annealed) that it is easy to shape by hand. The tubes can be rolled in the fingers and the ribbon pressed onto the metal edges with ease. The edges of the tail, for example, are long and curved in contour, yet the flexible ribbon can be guided along them, following each change of contour. Furthermore, this application of the ribbon-clips is achieved while the two halves are still separate, so that manipulation is straightforward and no heat is required. Getting solder to flow evenly along such a long and curved seam would be far more difficult.

Figure 25d presents a slightly different interpretation of the configuration and function of the ribbon-clips as suggested by Cyril Stanley Smith (personal communication). Smith argues that the clips were joined, back to back, along their midline (either through pressure welding or sweat-welding) *before* they were mounted along the edges of the tail-halves. He presumes that, at this stage, the clips were in a cold-worked condition, and that the resultant springiness of the metal in conjunction with the overall design of the clip was sufficient to hold the two tail-halves together. In his view, the primary function of the clips was a mechanical one, to hold the halves together and in alignment during the ensuing heating operations. No additional pressure or wrapping of the parts was necessary. The good thermal qualities of the clips, he feels, were strictly secondary. While this interpretation is certainly plausible, Lechtman feels that the clip metal was much too thin and of insufficient strength to have served mechanically in this way, even in an unannealed condition.

A look at several photomicrographs of sections through the tail seam affords further insights into the nature of the bond achieved. Figures 26, 27, and 28 illustrate just one section through the seam. In Figure 26, which shows a polished but unetched section, the top surface corresponds to the interior of the tail, the bottom to the exterior. The thickness of the metal of the right tail-half is approximately the same as that of the left at the region of the seam. The two halves are joined through only about half this thickness, for there is a gap between the two sides from the center of the seam out through the interior surface. Note also that this section was made in the region of the seam where the tubes are flattened and distorted from their original, roughly oval shape. This is quite clear in Figure 26, where the tube associated with the interior surface of the right tail-half is not only elongated but pushed down in the middle to touch the tail metal itself. The corresponding tube on the interior surface of the left tail-half originally took a similar form, but the original rolled-up edge is now missing. The tubes on the exterior surface of the tail have been ground away, only vestiges appearing on the photomicrograph. This finishing of the seam on the outside after the sweat joining was complete will be discussed in section *c*.

Figure 27, illustrating an etched detail of the join, shows how each clip fused completely to its respective tail-half at the edge itself, but the two clips fused to each other only at the exterior end of the join. The worked and annealed structure of the tail metal and the clips is continuous wherever fusion occurred, the small grains with annealing twins running uninterruptedly across the bonded zone. The clips evidently fused at their exterior ends as well, for the bit of clip metal remaining on the outside surface is one thick,

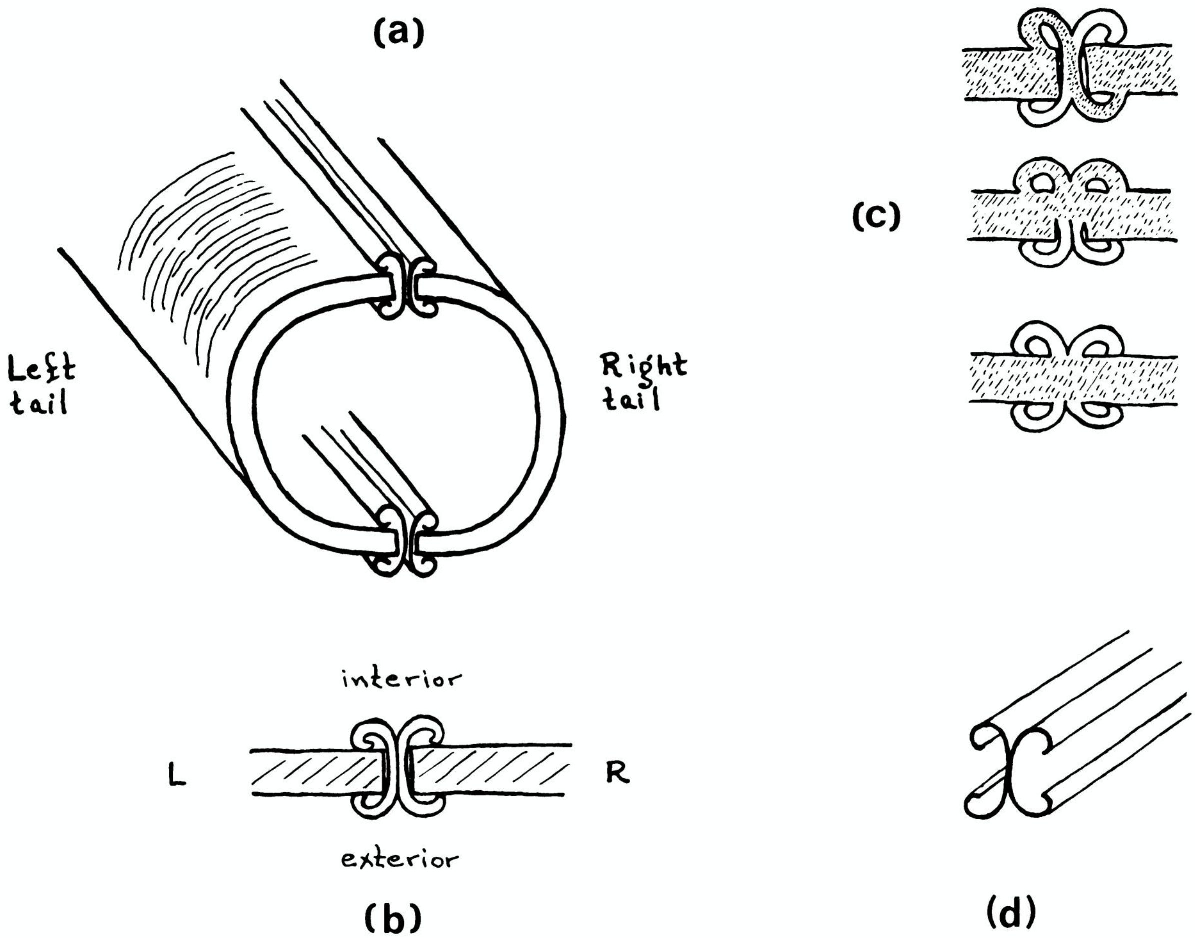


Fig. 25 Diagram illustrating configuration of ribbon-clips at a seam. *a.* Clips pressed along length of seam, following seam contour outside and inside. *b.* Cross section of seam shown in *a. c.* Variations in the bond configuration across the join. *d.* Clips joined along their middle before mounting on seam edges.

continuous piece. On the other hand, at the interior surface, the clip at the left did not bond with the tail metal, as the dark line representing the space between them clearly shows. The corresponding tube on the right side fused with the surface, as can be seen in a detail of that zone shown in Figure 28. Again, the worked and annealed structure of the tube metal is continuous with that of the tail at the zone of bonding.

What these and other, similar photomicrographs make clear is that the melting of the ribbon-clips was never complete, nor was it meant to be. In all cases they retain their original shape. The seam was never brought to a high enough temperature nor sustained at that temperature long enough to melt the added metal entirely so that it ran like a true weld filler. Such a regime would probably have ruined the piece, for the tail metal itself would have begun to melt and flow. Instead, the seam was heated until only its surfaces began to melt or to sweat—the surfaces of the tail metal as well as the surfaces of the ribbon-clips. The clips, being of much thinner metal than the tail, began to sweat first, thus initiating the bonding ac-

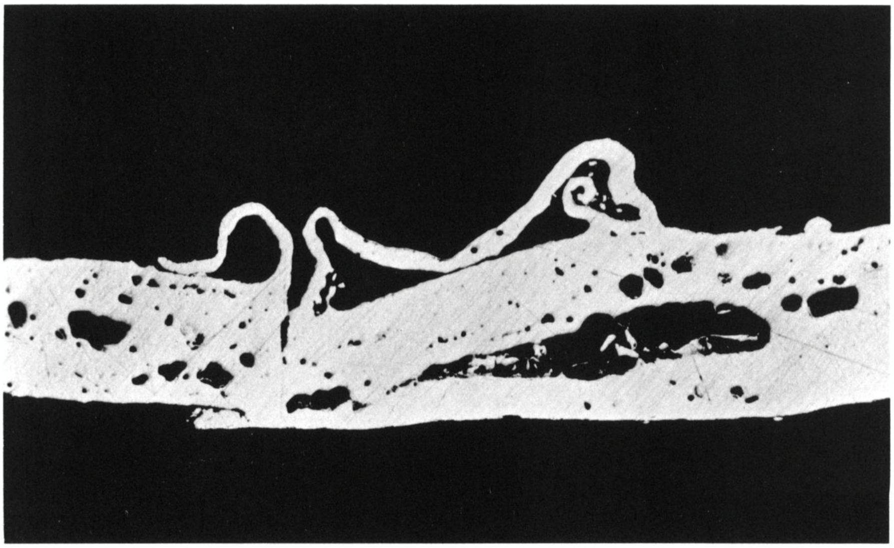


Fig. 26 Chicago jaguar (x100). Section through tail join. Note tubes intact on interior surface, but ground away on exterior.

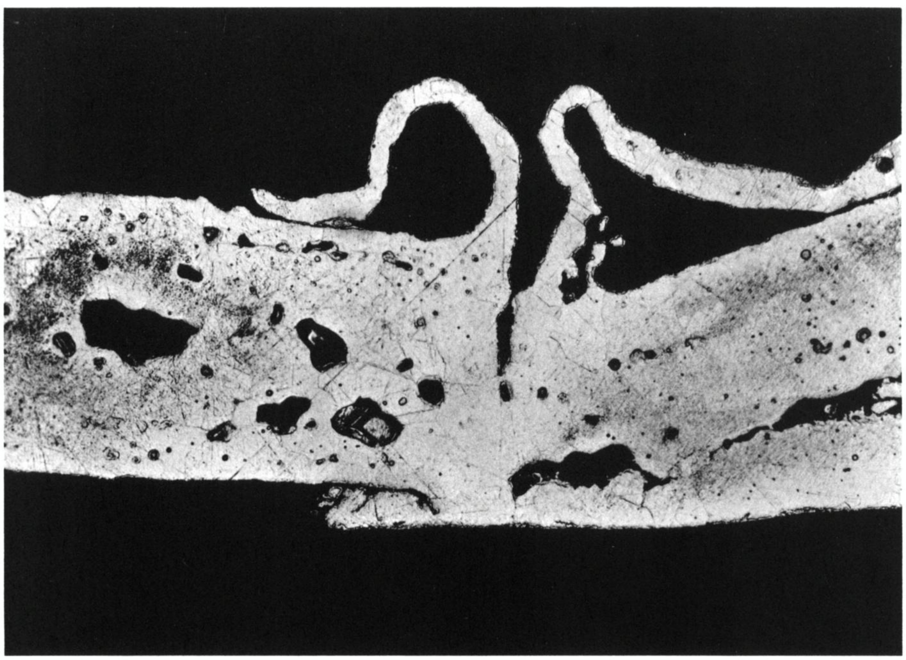


Fig. 27 Detail of section in Figure 26 (x200). Note small, equiaxed grains containing annealing twins continuous across the join. Etch: KCN + $(NH_4)_2S_2O_8$.

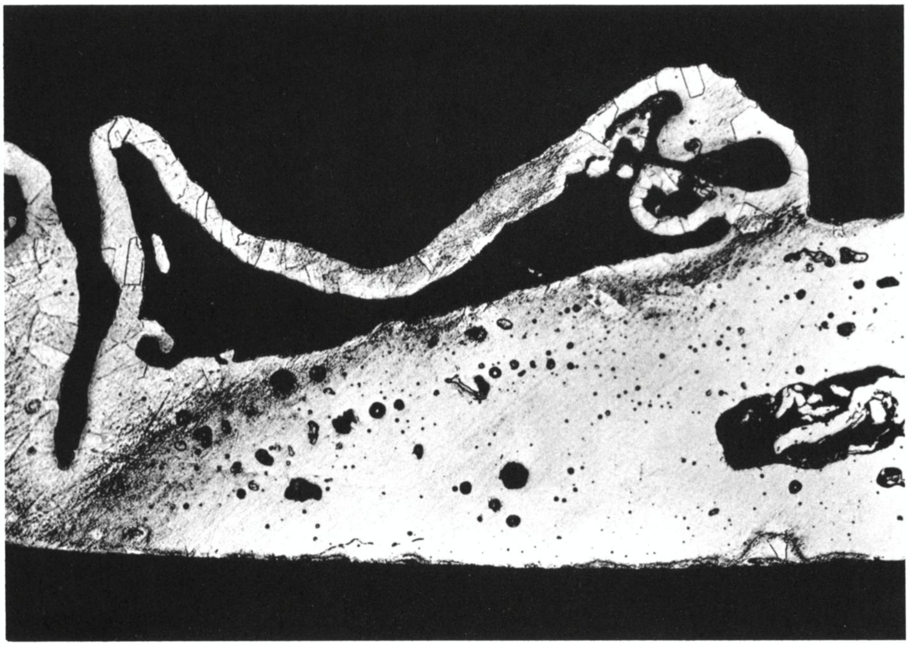


Fig. 28 Detail of section in Figure 26 (x200) showing bonding of rolled tube-end with tail metal and continuity of worked-and-annealed structure across the bond. Etch: KCN + $(NH_4)_2S_2O_8$.

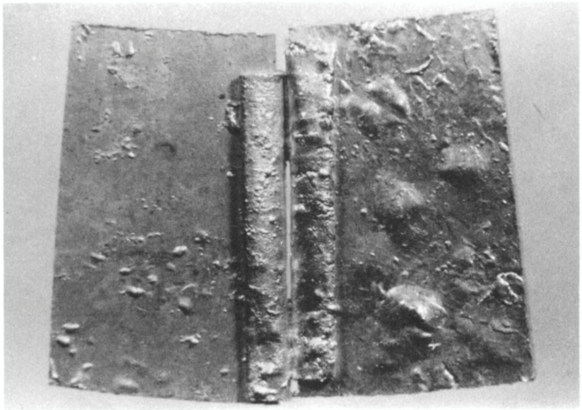
tion. As soon as enough surface metal became molten and could fuse, the heat source was removed and the join allowed to cool and solidify. The join is thus clearly designed to maximize the advantages of surface sweating, and its effectiveness depends upon accurate control of heat to a localized area.

To explore further the metallurgy of this type of join, an attempt was made to reproduce it. We cast an alloy of roughly the same composition as that of the tail metal (16% Ag, 9% Cu, 75% Au), and forged a piece of sheet metal from the ingot through a number of hammering and annealing sequences. Several pieces were cut from the resulting sheet and their thickness reduced even further in a rolling mill. This provided both the sheet metal to be joined (0.6 mm. thick) and the ribbon for the clips (0.13 mm. thick). The sweat-welding experiment itself was conducted by Henry Shawah, a professional goldsmith working in Cambridge, Massachusetts. He is the first goldsmith from the United States to have been honored by a solo show at Goldsmiths' Hall of the Worshipful Company of Goldsmiths in London; that exhibition took place in 1970. Shawah's opinion was sought on the feasibility of the joining procedure before he attempted to reproduce it. He formed the ribbons into clips of the general shape shown in Figure 25a, using finger pressure and occasionally a pair of pliers. Pliers would not have been necessary had our ribbon been as thin as that on the jaguars, however (0.13 mm. : 0.02 mm.). The metal was extremely supple and easy to form. The clips were pressed onto the two edges to be joined. Then both pieces of metal were laid side by side, on top of a charcoal block. In this position, with the clips butted along their length, but without any external force pressing them together, the whole piece was heated with a large and gentle oxy-acetylene flame that totally enveloped it. In this way, its temperature was raised in an atmos-

phere almost free of oxygen, preventing the formation of copper oxide scale on the surfaces. The surfaces of the thinner clips began to sweat before the surfaces of the thicker metal sheet. At the point when all the surfaces were "shimmering," the flame was removed and the join allowed to cool.

The results of Mr. Shawah's experiments are illustrated in Figures 29–33. In Figure 29, we see the two joined pieces lying flat, with the tubes at the seam. Note that the central thirds of the tubes have not joined with one another, whereas the bottom and top portions have. In Figure 30, which shows an end view of the same piece, the shape and position of the clips are quite clear. This piece was mounted and examined metallographically to compare the reproduced join with those on the jaguar.

Figures 31 and 32 illustrate sections made at various positions along the seam. In Figure 31 we see that the central portions of the clips have joined and that three of the clip-ends have bonded well to their respective sheets. In addition, the clip at the right has bonded to the edge of its sheet in the plane of the join. The resulting joint is strong and effective. In Figure 32, no bond has occurred between the two clips, although each clip is successfully joined to its respective sheet (see Fig. 23 for comparison). This section was made through the central portion of the seam (see Fig. 29) where no bond was accomplished. The photomicrograph of Figure 33 is an etched detail of the section shown in Figure 31. We see the sweat-welded join between the upper surface of the sheet and the surface of the tubular clip-end. As in the case of the joins on the jaguars (Fig. 28), the worked and annealed structure of the sheet and the clip is continuous across the join, indicating that only the surface metal melted while the body of the clip and sheet remained unchanged. We can see the outline of the original surfaces of the clip and sheet by virtue of the thin lines of tiny black dots representing copper oxide scale that was present on these surfaces during heating. The curved surface of the once-molten metal that now lies between the clip and the sheet at the joint itself is characteristic of the surface tension that arises be-



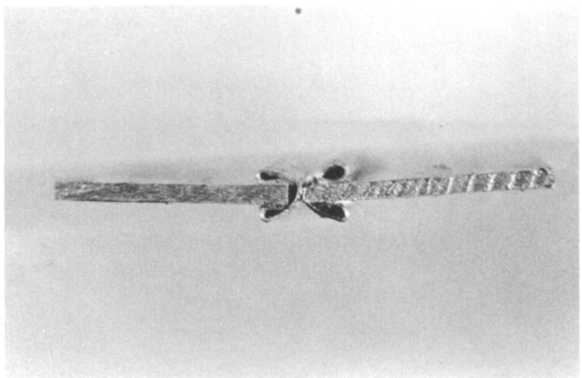


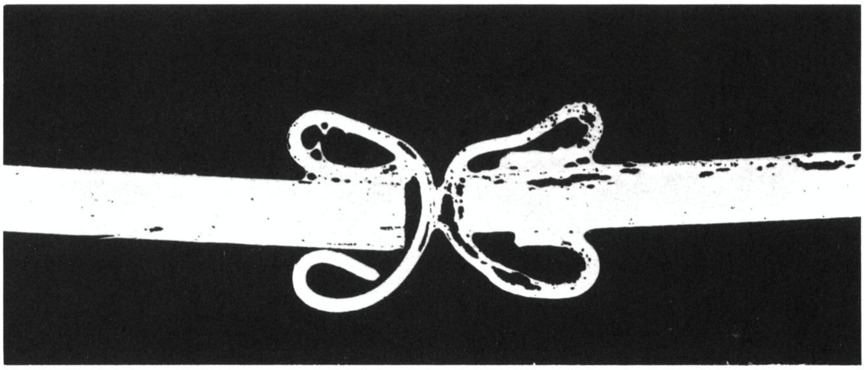
Fig. 29 (top) Experimental sweat-welded join (x3.5). Two pieces of sheet gold with ribbon-clips along their common edges. Bonding has occurred at upper and lower thirds of the seam. Note blisters on metal surfaces.

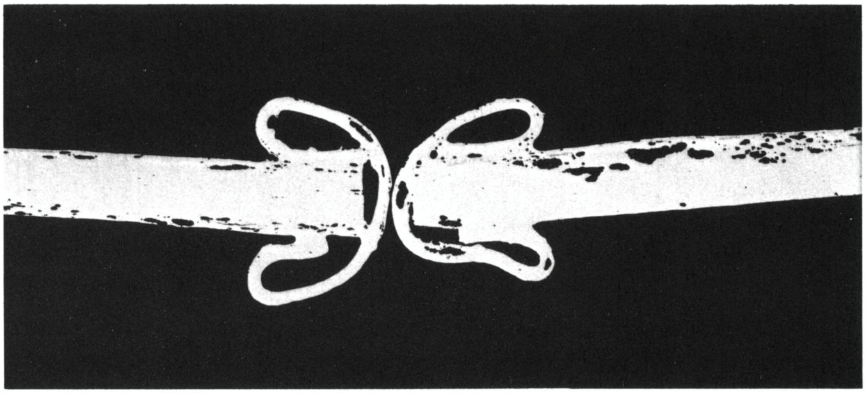
Fig. 30 (above) Experimental sweat-welded join (x3.5). End view of the pieces shown in Figure 29.

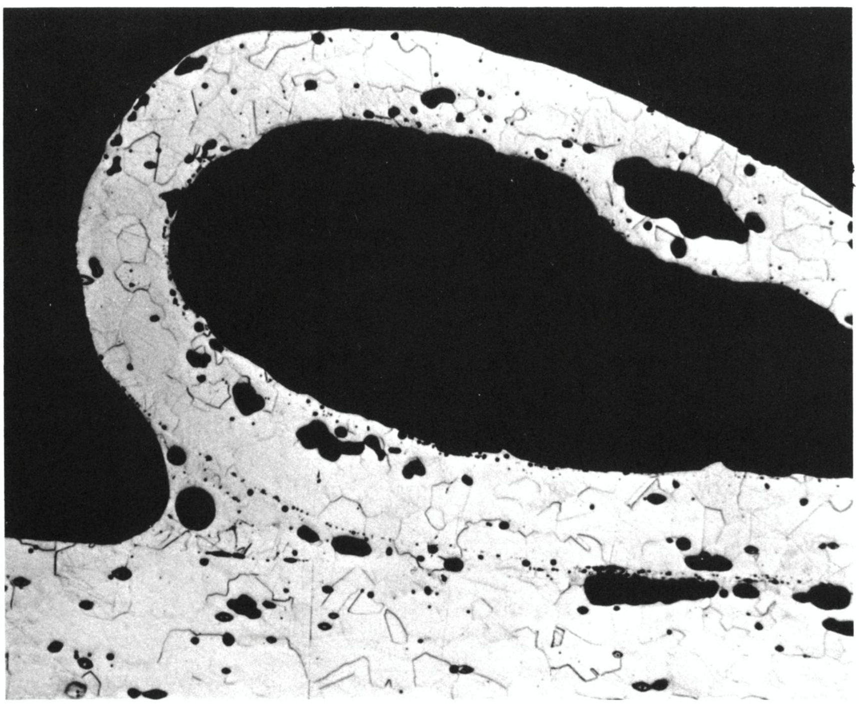
Fig. 31 (right, above) Experimental sweat-welded join (x13). Cross section showing bonding of portions of the clips to themselves and to sheet metal.

Fig. 32 (right, center) Experimental sweat-welded join (x13). Section shows no bond between the ribbon-clips at the joint and corresponds to the unfused middle third of the seam in Figure 29.

Fig. 33 (right, below) Experimental sweat-welded join (x100). Etched detail of section shown in Figure 31. Note continuity of worked-and-annealed grains across the join between rolled end of ribbon-clip and surface of metal sheet. Etch: KCN + $(NH_4)_2S_2O_8$.







tween the liquid metal as it cools and shrinks and the solid metal that bounds it on both sides and which is wet by the liquid. In general, all these sections on the experimental sample are quite reminiscent of similar sections through the join on the tail of the Chicago jaguar (see, for comparison, Figs. 23, 26, and 28).

Mr. Shawah felt that sweat-welded joins of this type could have been made easily with the equipment available to Andean smiths, as long as the parts to be joined were surrounded by charcoal burning with a slow but steady flame. This would ensure a reducing environment in which to operate and a fairly uniform temperature distribution throughout the object as a whole. The join might then be effected in a number of ways. (1) The temperature of such a charcoal bed would be raised slowly and steadily through the agency of a forced draft until the object was at the point of sweating. As soon as sweating occurred, the piece was removed from the charcoal. (2) Once the object had reached the ambient temperature of the slow-burning charcoal, perhaps about 850°C, a carefully directed and focused blast of heat, such as is obtained with a fine-bore blowpipe, would be brought to bear upon the seam itself, causing sweating and bonding there but avoiding it elsewhere on the object. The high overall temperature of the piece would ensure that the heat directed to the seam would not dissipate too rapidly. (3) A combination of (1) and (2) could be used, in which the temperature of the fire was raised close to the sweating temperature of the metal, at which time a fine blowpipe was used to concentrate the heat at the seam.

Clearly the crucial factor in all these operations is temperature control. The charcoal bed must flame gently, and the heat must increase slowly and uniformly. The object, surrounded by the charcoal, is enveloped in an atmosphere of carbon monoxide. Cyril Smith (personal communication) has pointed out that, if the tip of a blowpipe were inserted well into the CO layer, the jet of air emitted from its fine bore would burn in the gas much as oxygen burns in a modern oxy-acetylene torch. This would produce an intensely hot, local, and easily controlled jet of heat that could be directed to the appropriate spot on the object. We have ample evidence that Peruvian smiths were well acquainted with large blowpipes and used them to provide forced drafts to their fires. Numerous passages in the chroniclers of both Mesoamerica and the Andes—such as Ralegh (1848: 96), Oviedo (1959, III: 11), Díaz (Saville 1920: 13), Benzoni (1857: 73, 250–1), Garcilaso (1966, I: 131, 539), and Sahagún (1951–70, Book 9: Ill. 62; Book 11: Ills. 793, 796)—describe forced drafts to *huayra*, brazier, or crucible fires through the agency of blowpipes. Recently our attention has been called to a Moche ceramic pot depicting a scene in which some metallurgical operation is taking place with those in attendance blowing through long tubes, presumably to raise the temperature of the fire they tend (Donnan 1973). All these data indicate that such techniques were widespread and effective. We do not have similar evidence for the fine blowpipe, although the measure of heat control implied by the quality of the Peruvian joins seems to argue for its employ.

We should note here the highly porous nature of the clip and sheet metal we used in our experiments. The porosity manifests itself as large black voids on the cross sections and as large blisters that formed on the surfaces of the sheet when it was heated to produce the join (Fig. 29). This porosity resulted from poor technique on Lechtman's part when she hammered the sheet from the original ingot, which was not at all porous. Because of failure to anneal the metal at high enough temperatures after each round of hammering, the sheet became too brittle. Small cracks developed on its surfaces; these then entrapped air, which gradually became dispersed in the body of the metal as hammering proceeded. When the sheet was heated to effect the join, all of the metal was raised to a sufficiently high temperature for the entrapped gas to expand, resulting in blisters on the surface and large pores at the interior. Interestingly, the Peruvian metal exhibits exactly the same kind of porosity, which we can see both in the cross sections of the tail join (Figs. 26 and 36) and on the inside surface of the tail, where the blisters are quite apparent

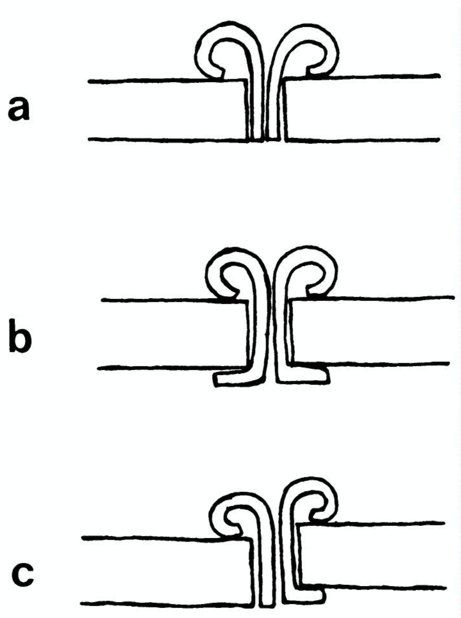


Fig. 34 Diagram illustrating effects of finishing operations on external appearance of a seam. *a*. Ribbon-clips ground down flush with exterior surface. *b*. Ends of clips ground slightly proud of surface; seam exhibits two adjacent strips along its length. *c*. One side of join offset with respect to the other, leaving one clip proud of surface; seam exhibits single strip along its length.

(Fig. 21). This porosity may result from a similar shortcoming in the annealing procedures the Peruvian smiths used when they manufactured their sheet metal—a fortuitous, if unexpected, result! It is also quite possible, however, that the original ingot used to manufacture the sheet metal contained copper oxide inclusions. Then, when the sheet was heated under reducing conditions, such as those in effect during the sweating operations, hydrogen diffused rapidly into the metal, combining with the oxides to form water. The water vapor then expanded, producing surface blisters and bubbles within the metal.

c. External appearance of the sweat-welded seams

The explanation for the various configurations of the welded seams that one notices on the exterior surfaces of the jaguars is now clear. After a join is made, the tubular clips on the outside have to be ground away for the seam to assume a smooth and flat surface, more or less at the same level as the metal adjacent to it. The seam metal would remain proud of the surrounding surface and would appear as a single strip or as two strips depending upon the relative position of the metal halves at the time of joining. The diagrams in Figure 34 illustrate the configurations the seam might take. In Figure 34a, both halves of the metal are flush at the surface, and the external tubes have been entirely removed, leaving the surface level at the seam. In Figure 34b, the two metal halves are flush, but not all of the clip has been removed in the finishing operations, leaving two proud strips of metal at the seam, lying side by side. In Figure 34c, the two metal halves are offset, so that one clip is ground flat but part of the other remains, leaving a single strip at the seam that may or may not be proud of the surface. As can be seen in Figures 14 and 16, the appearance of any one seam changes according to these effects of relative metal position and amount of surface finishing.

These factors are made graphic in Figures 35 and 36, both of which are sections made very close to one another through the tail seam. The left external tube is visible in Figure 35, and it has been ground and polished flush with the metal surface to the right. Note how the two tail-halves are offset with respect to one another. A little further along the seam (Fig. 36), almost all of the clip has been removed, the general contour of the surface at the seam taking its shape from the curve of the metal on the right. It is evident from these photomicrographs, as well as from Figure 23, that the external appearance of the seam at all these points varies in ways that reflect the situation of the seam at the time of sweat-welding.

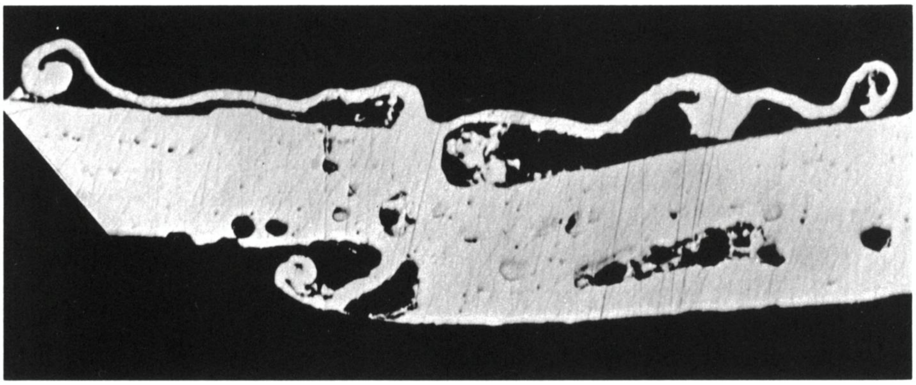
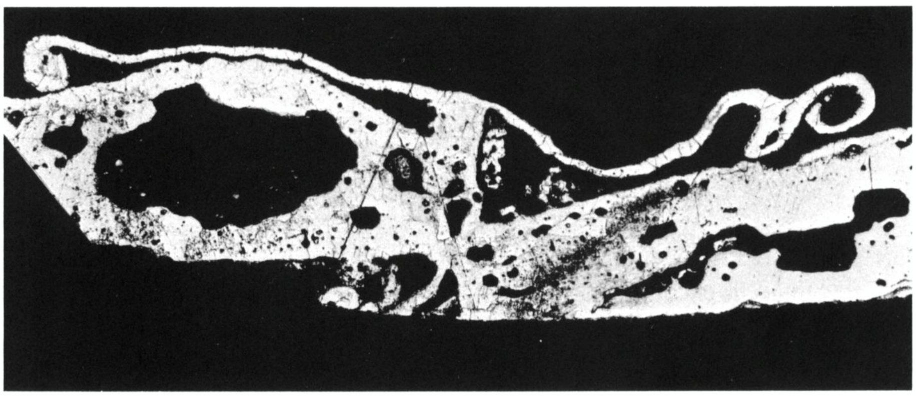


Fig. 35 (above) Chicago jaguar (x100). Section through tail midline join showing rolled end of a ribbon-clip on exterior surface after surface finishing.

Fig. 36 A section adjacent to that in Figure 35 (x100). The end of the left external clip is almost completely ground down flush with the surface at the right.



THE SOLDERED JOINS

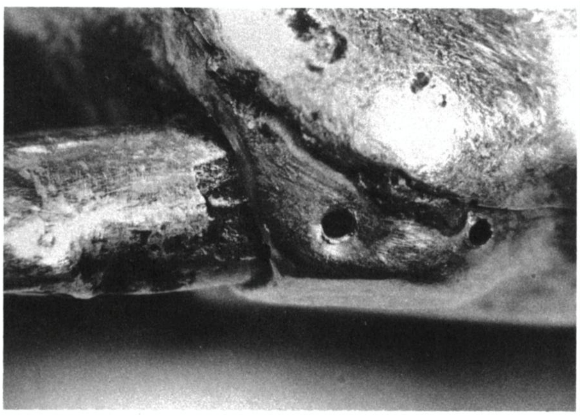
After the extremities were made, they were joined to the body by soldering. The solder used throughout is a silver-copper alloy (roughly 52% Ag, 48% Cu, as determined by quantitative metallography), which melts at approximately 860°C. This melting temperature may be compared with the temperature at which the gold alloy is molten, approximately 930°C.

Before the extremities were attached, the upper and lower parts of the body were soldered together. A sweat-welded join of the type described for the extremities would have been extremely difficult in the case of the body join, because the body is not made of halves with identical contours and because the top and bottom edges are not coplanar, as are the edges on all the extremities. Instead, the goldsmiths chose to overlap the upper body onto the lower and to insert individual pallions of solder at intervals along the join, fitting them up into the space created by the overlapping edges. The small gold tabs that protrude intermittently from the edge of the lower body onto the upper portion (see Figs. 1–3) served to register the top and bottom during soldering. They did not constitute a true mechanical join as such, and

the body join of the Chicago jaguar was accomplished without them.

The solder pallions were most often cut into rectangular strips of appropriate length and inserted at several spots along the join, often with considerable space between them. Examples of the pallions are illustrated in Figures 37–39. Figure 37 shows a short strip of solder pushed half way up under the upper body edge at the position of the proper left shoulder of the animal. Another such pallion is visible at the join between the left leg and the body where the leg fits into the opening in the lower body. In Figure 38, we see two other pallions along the body seam on the proper right side of the animal's head. The pallion situated nearer the mouth is still metallic and shiny in appearance, whereas the piece posterior to it has corroded and is black, rather disfiguring the object and calling attention to the seam. These corrosion products, comprised of copper and silver sulfides and silver chloride, generally appear gray to black in color and are prominent at most of the jaguar body seams (Figs. 3, 6, and 7). Figure 39 illustrates two of the four pallions that once joined the tail of the Chicago jaguar to its body (compare with Figs. 19, 20, and 22).

Once the strips of solder were in place, heat was applied locally either: (1) to melt them so that the solder would run freely along the seam, producing the bond (this is usually the case at the ear joins); or (2) to fuse them *in situ* without a sufficiently long



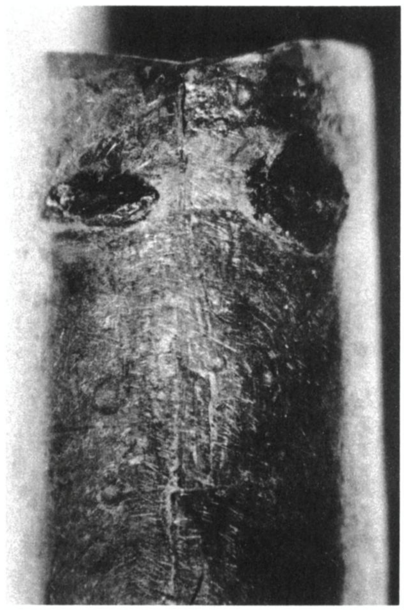


Fig. 37 (above, left) Chicago jaguar (x3.5). Rectangular pallions of silver solder at join between leg and body and between upper and lower body parts.

Fig. 38 (left, below) Chicago jaguar (x3.5). Rectangular pallions of silver solder along body seam. The black appearance of the posterior pallion results from a mixture of silver and copper corrosion products.

Fig. 39 (above) Chicago jaguar (x5). Two pallions of silver solder near open end of tail. These once joined the tail to the body.

period of heating to allow for much flow of metal along the seam. This absence of flowed solder is quite clear, not only from the appearance of the pallions along the body seam of most of the jaguars, but from the radiographs as well. In Figure 13, for example, the spongy solder strips are located at discrete positions along the body seam with little or no visible solder joining one pallion to the next.

It is this local "spot-soldering" that probably resulted in the failure of some of the joins, as already noted in the case of the Milwaukee leg and the Chicago tail. It is difficult to say whether such failure was a result of insufficient diffusion of the atoms between the gold and the silver-alloy solder caused by too brief an interval of heating at the melting point of the system, or because of the poor geometry of the join itself. Some of the pallions seem never to have made good contact with both the surfaces they were meant to join, even before they were heated. The rather summary treatment of the soldered joins is surprising in view of the tremendous care taken with the sweat-welds.

One of the four pieces of silver solder at the open end of the Chicago tail (Fig. 39) was tenuously attached to the surface by one corner. The pallion was removed from the tail, mounted, and examined metallographically. An etched cross section is shown in Figure 40. The long, thin layer of metal at the bottom of the section was in contact with the tail; the much shorter upper surface touched the wall of the body at the rear opening for the tail. The etchant was effective in bringing out the structure of that portion of the solder which is still essentially the binary Ag-Cu alloy (the dark portions on the photomicrograph). It was far less able to attack the upper surface or the bottom right surface where sufficient gold had diffused into the solder from the body metal or the tail metal to produce a ternary Ag-Cu-Au alloy that would not

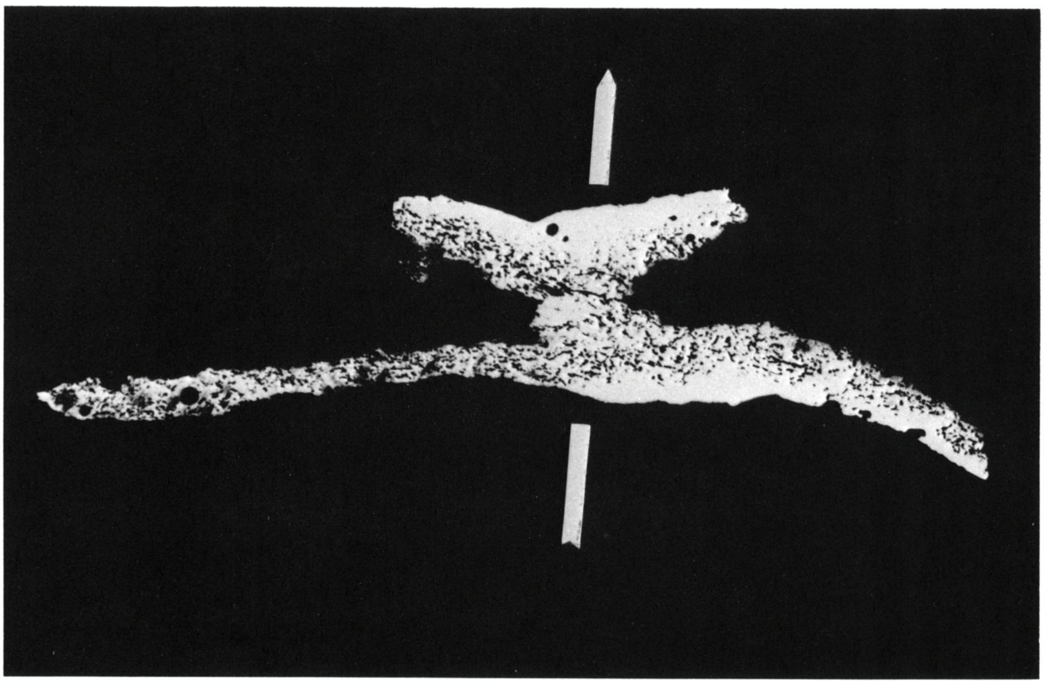


Fig. 40 Chicago jaguar (x65). Cross section through silver solder pallion removed from tail. Upper surface originally bonded to body metal, lower surface to tail metal. Arrow indicates direction of microanalyser traverse. Etch: $FeCl_3$.

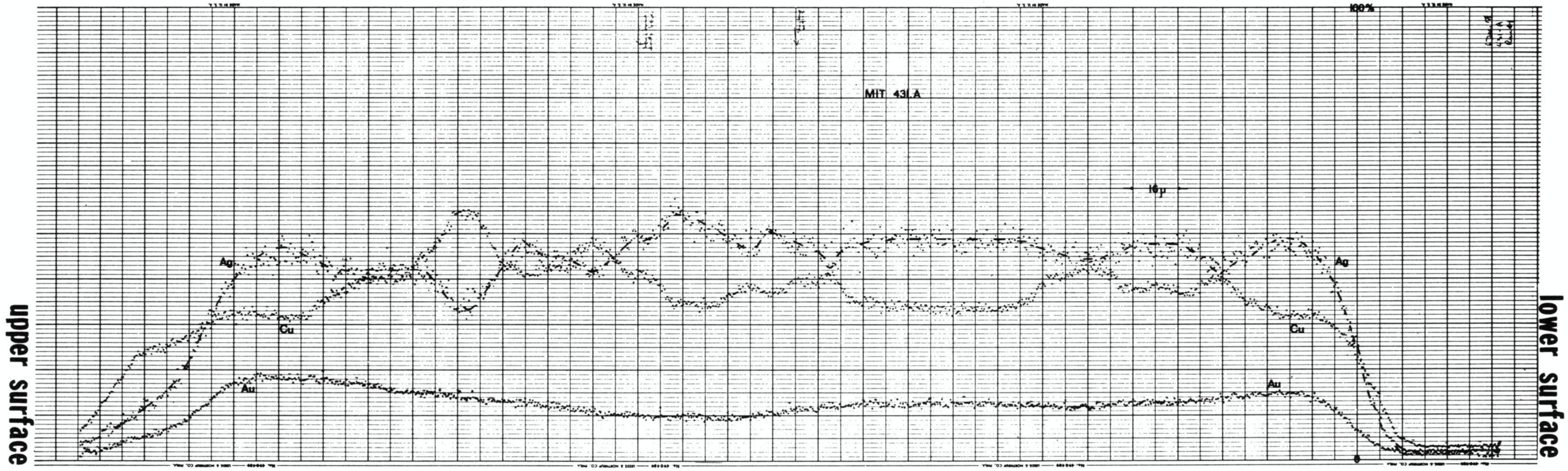


Fig. 41 Chicago jaguar. Electron microanalyser scan across silver solder section shown in Figure 40.

respond to the etchant. These zones of gold-enriched metal appear as white areas on the photomicrograph.

The section was studied with an electron microanalyser to obtain a plot of the change in composition of silver, copper, and gold across the thickness of the pallion. The path of the electron beam across the section, from lower surface to upper surface, is indicated in Figure 40. The probe trace is given in Figure 41. It shows a low and fairly uniform concentration of gold throughout the solder, probably picked up during the soldering operation by diffusion of the gold into the liquid silver-copper alloy. The increase in gold concentration at both surfaces, amounting to a doubling of the gold content at the upper surface, records this diffusion effect. The results of the probe trace corroborate the interpretation gained from the photomicrograph in Figure 40. Surface metal scraped from a pallion on the tail and also from the body seam of the Chicago animal was analysed by neutron activation. In one case, the composition of the solder was 47.7% Ag, 35.3% Cu, 17% Au. In the other, it was determined as 48.6% Ag, 23.3% Cu, 28.1% Au. These values correspond well with the picture afforded by the probe trace in Figure 41.

Figure 42 is a detail of the thin layer of metal at the lower left of the section. Here the etchant has brought out the structure of this silver-copper solder that solidified through the formation of primary dendrites of the copper-rich phase (dark etching), which were eventually surrounded by eutectic (light etching).

THE METALLURGICAL JOINS AS A SYSTEM

The design of the joins on these jaguars was influenced by two overriding factors: (1) their cosmetic appearance, and (2) the sequence in which the parts of the animals were assembled. Although we are not entirely certain about the way in which these jaguars were mounted or worn, it is clear that the back, head, and tail are their most prominent features and that these were uppermost when viewed. The belly and

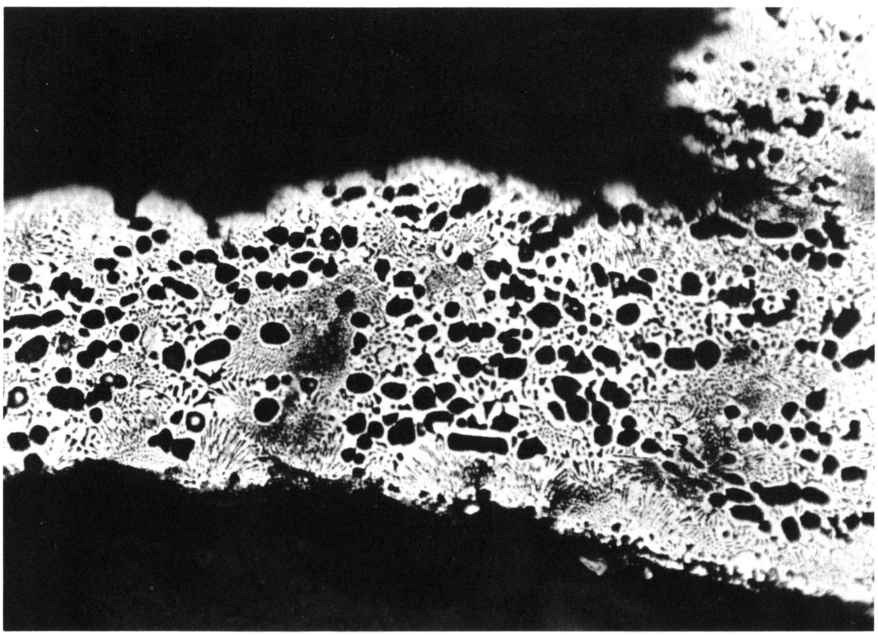


Fig. 42 Etched detail of a portion of the silver solder shown in Figure 40 (x500). Primary copper-rich phase (dark etching) surrounded by eutectic (light etching). Etch: $FeCl_3$.

underside of the animals are carefully finished but were certainly hidden much of the time that the jaguars were displayed. Consequently, the seams on the tail and ears in particular were always in full sight, and the choice of a joining procedure that retained the same metal color at these seams as on the surrounding surfaces was a deliberate choice made for cosmetic reasons. Indeed, these seams are apparent only if one looks for them with care.

By contrast, the long seam joining the upper and lower parts of the body utilizes a silver solder whose color is strikingly different from that of the body metal. But this quite noticeable seam was not even visible when the animals were viewed from above, as is evident in Figure 5. The fact that it was hidden when so viewed lends weight to the argument that the animals were oriented to be seen from the top and not from the side, as we are wont to photograph them (Figs. 1, 2, 3, and 6).

The need for a soldered join at the body seam has already been discussed in terms of the configuration of the joint itself. A solder that would melt at a temperature below that of the gold-alloy body metal was imperative. Similarly, the tail, ears, and front legs were soldered to the body at a temperature that would not affect their previously executed sweat-welded seams, which, if overheated, would have fallen apart. At the same time, the fact that the difference in the melting temperatures of the sweat-weld metal and the solder is not great (approximately 70°C) points out the reason for the spot-solder technique, which concentrated the heat at discrete areas from which it was rapidly dissipated. Whereas the sweat-welding of the extremities was probably achieved by first heating the entire extremity almost to the sweating point and then concentrating the heat at the seam, the soldering seems to have involved heating only the local area covered by each solder pallion. This must have involved a fine blowpipe or some other mechanism by which each pallion could be heated while the rest of the animal remained relatively cold.

The jaguars exemplify the metallurgical joining system familiar to all goldsmiths who have developed solders. Particular alloys are chosen for particular joins according to their relative melting points. As parts are assembled, the joins made first utilize the higher melting solders; thereafter, successive joins employ solders of decreasing melting point. The unusual characteristic of the jaguars is that the "solder" of highest melting point is, in fact, the same alloy as are the metal parts themselves, so that the initial joins are sweat-welded rather than actually soldered. Nevertheless, the joins comprise a system designed to be metallurgically and aesthetically viable.

Conclusion

> . . . Chavín gold was an early development, brilliant in style and in techniques of manufacture. It was, however, largely an isolated phenomenon which contributed comparatively little to subsequent cultures. Forms and processes apparently had to be created a second time. Chavín represents an unusual metallurgical stage when the melting of metal had been discovered and its use as a solder mastered. . . . (Lothrop 1951: 239)

Lothrop, writing in 1951, did not have available to him the wealth of metal objects that presently confronts us from the north of Peru, particularly from the Vicús and Frias culture areas. It is the careful study of this corpus which will allow us to re-evaluate Lothrop's conclusions as to the uniqueness of Chavín metallurgy and, concomitantly, its lack of persistence in the cultures that immediately followed it. In that re-evaluation, however, we will do well to heed closely Lothrop's observation about the overlapping of cultures and their contemporaneous manifestations

in different river valleys. In compiling a list of metallurgical inventions in northern Peru, beginning with Chavín and ending with Chimú, he notes that his table

> . . . indicates a decline in metalworking during the Salinar period which lasted into the Gallinazo, when casting was invented or acquired and copper was discovered. As a matter of fact, these so-called periods must have overlapped in part because there are direct links between Mochica and Chavín. Cultures which are successive in one valley may have been contemporaneous elsewhere, a possibility deserving greater attention than it has received. (Lothrop 1951: 235)

We would like to suggest that, in fact, the sophistication of late Chavín metallurgy did not end abruptly, but was carried on in the far north, both in the highlands and on the coast, the fruits of which we now recognize, at least in part, in the early Vicús and Frias materials. That is not to say that the peoples of the far north were the direct inheritors of Chavín traditions, but that, by the so-called transition Chavín period (after Sawyer 1968: 24 and chart), roughly 500–300 B.C., the far north of Peru had developed as a culture zone that could take advantage of the impetus of a viable metallurgy to its south and of a similarly dynamic metallurgy to its north, in present-day Ecuador. It was in this northern zone of Peru that Chavín metallurgical inventions could be continued, and it seems obvious that they were.

For example, if we look at the kind of welding/soldering system we have described for the jaguars and attempt to trace its antecedents, we can find them in Chavín examples, just as we find them in Frias examples (which are more likely to be contemporary with the jaguars than earlier). Lothrop cites several instances of the system both in the artifacts associated with the woman's grave at Chongoyape (1941) and in those in the Bliss Collection (now belonging to Dumbarton Oaks), among which are the spoons that we have already discussed. In two of the Chongoyape pins which are made of sheet metal, the hollow pinheads were fashioned separately from the shaft. Each pinhead consists of halves that were shaped over a model and subsequently welded along their midline. Afterwards, each completed pinhead was soldered to its respective shaft (Lothrop 1941: 259–60, Plate XX, *c* and *d*).

Thus, the sudden burst of creative metallurgy characteristic of the Early Intermediate Period, and particularly apparent in the Moche Valley, was not based primarily on a reinvention of older techniques but rather upon the utilization of a body of knowledge that was present and thriving in the valleys to the north—and perhaps, for all we know, in the Moche Valley as well. It was on this foundation that the Mochica went ahead and, as extraordinary innovators in pyrotechnology, became the champions of a metallurgical practice that was never again equaled in Peru.

If the group of jaguars we have described falls somewhere in the period between late Chavín and early Mochica, as we feel that it does, it concretely represents the persistence of a sophisticated Early Horizon metallurgical technology and its availability to the smiths of a later age.

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